



Integrating Trees with Livestock Grazing:

to reduce use of conventional fencing (DAV-80A)

**Report for the
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by
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Foreword

Trees have the potential to increase sustainability and productivity of agriculture. However, establishing trees on farmland in the presence of browsing livestock is a major challenge confronting land managers. Conventional fencing and treeguards are expensive.

This report explores four ways in which the use of fencing can be replaced by cheaper options. These include using trees of low palatability; trees that recover well from browsing; the use of repellents to protect trees from browsing; and training of sheep through conditioned feed aversion to avoid eating eucalypt seedlings.

Tree planting on farms is becoming more widespread and popular. However, it must be recognised that research is required to allow adaptation of our farming systems to make the best use - economically and ecologically of trees.

This project is one of a series of projects within the RIRDC/LWRRDC/FWPRDC Joint Agroforestry Program which aims to develop practical agroforestry and farm forestry systems for the combined purposes of commercial production of forest products, increased agricultural productivity, and sustainable management of natural resources within the agricultural environment.

Peter Core

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Table of Contents	Page No.
1. Non-technical summary	1
2. Background	2
3. Objectives	2
4. Introductory technical information	2
4.1 sheep browsing	3
4.2 grazing management	3
4.3 tree species	4
4.4 recovery from browsing	4
4.5 repellents	5
4.6 conditioned food aversion	5
5. Research methodology	6
5.1 the effect of height of tree seedling on sheep browsing.....	6
5.2 sheep browsing preference amongst 18 tree species.....	6
5.3 simulated browsing damage.....	7
5.4 tree susceptibility to browsing damage at different times of the year.....	8
5.5 the use of repellents to protect tree seedlings	8
5.6 conditioned food aversion.....	9
5.7 statistical analyses.....	10
6. Results and discussion	10
6.1 the effect of height of tree seedling on sheep browsing.....	10
6.2 sheep browsing preference amongst 18 tree species.....	10
6.3 simulated browsing damage.....	12
6.4 tree susceptibility to browsing damage at different times of the year.....	13
6.5 the use of repellents to protect tree seedlings	14
6.6 conditioned food aversion.....	15
7. Implications and recommendations	18
8. Intellectual property	19
9. References	19
10. Appendices	21

1. Non-technical summary

Establishing trees and other vegetation on farmland in the presence of browsing livestock is one of the major challenges leading toward sustainable land use. Currently most vegetation is protected from grazing animals with expensive fencing or individual tree guards. This can represent 70% of the cost of any given revegetation project. Less expensive management strategies that deter livestock from eating young trees are required. Such strategies are likely to have a major impact in helping to reestablish perennial vegetation in the low-medium rainfall regions of the country.

This project developed a better understanding of the factors influencing sheep browsing of trees and the effects on tree survival and growth through studies conducted at the Institute for Integrated Agricultural Development, Rutherglen in North East Victoria. Significant variation in browsing damage to 18 eucalypt and acacia species was measured with *E. globulus* and *E. maculata* being the least palatable. *E. camaldulensis*, *E. nitens* and the acacia species were the most severely browsed.

The effect of simulated browsing on the survival and growth rates of eucalypts varied with species and the severity of damage. Generally browsing of the side branches and some damage to the apical tip in the spring of planting had no effect on survival or growth. Browsing damage repeated in the following autumn significantly reduced the growth of some trees. Of the 5 species evaluated, *E. camaldulensis* and *E. melliodora* were the most tolerant of browsing while *E. maculata* suffered the greatest reduction in growth.

Another study investigated when during the year trees were most at risk from browsing. It appeared that trees were browsed more readily in the autumn prior to the opening rains when there was a shortage of forage available. Browsing damage was not observed to be greater in winter.

In simple 2-choice tests, sheep avoided hay treated with repellents formulated from dog urine and sheep dung but readily ate the untreated hay. Although offering short term protection and perhaps being a useful tool in combination with other management strategies, repellents that rely on olfactory cues alone are unlikely to reduce damage in the longer term. Animals learn preferences for food and they can be taught to avoid eating specific plants such as trees.

Sheep were trained to avoid eating seedlings of *E. camaldulensis* by offering them foliage and subsequently administering an emetic (lithium chloride) which induced mild nausea. The sheep associated eating the tree with the induced nausea. The aversion was developed in sheep within a few days and persisted for at least 3 months when the sheep were retested under controlled conditions in the sheep house. However in field trials, the level of tree browsing by the untreated sheep was also low which made comparisons difficult. Should the aversion break down in the complex field environment, methods for reimposing the aversion that are relatively quick and inexpensive to apply need to be developed.

'Windows of opportunity' exist for developing management strategies for grazing sheep in agroforestry and revegetation areas. This project has investigated some of the factors that need to be considered and identified possible components of a management system.

2. Background

Trees have the potential to increase the sustainability and productivity of farming. A major factor limiting the integration of livestock with trees is the lack of management practices that deter animals from eating desirable trees. Hence trees are generally protected from grazing animals by expensive fencing or individual tree guards. Protection can represent 70% of the cost of any given revegetation project (Campbell 1991), although the use of electric fencing can lower the cost. Landholders have identified this as a significant impediment to committing more land to revegetation or agroforestry (Prinsley 1991). Management systems that reduce the need for permanent fencing will have a significant impact on the revegetation of grazing land. The possibilities for farming systems to become more 'sylvan', as Campbell (1993) recommends, are greatly increased

For ease of management, livestock and trees are spatially separated, often permanently. Although there is scientific and anecdotal evidence that not all animals pose a threat to all trees all the time, the lack of management strategies that deter animals from eating trees has made this the safest approach for the landholder to adopt. However separating the tree and livestock activities has drawbacks.

The area available for grazing in agroforestry systems is reduced in the short term, whilst weeds and grasses may build up if left uncontrolled, provide a haven for vermin, and create a fire risk. The use of herbicides to control excessive herbage growth which could be turned into animal products is lost and this imposes another cost to the farmer. In addition, most tree planting becomes concentrated around the perimeter of paddocks to include existing fences. Widespaced trees or small clumps across the farm provide more shade for livestock, and are likely to use more rain where it falls and hence reduce recharge and lower watertables, but they are more difficult and costly to protect.

Greater understanding of the factors influencing browsing of trees by sheep is necessary to develop appropriate management strategies that can deter livestock from ingesting desirable trees.

3. Objectives

The main objective of the project was to identify and test various management strategies for integrating sheep grazing with tree growing in farming systems. This aims to:

- reduce the cost of establishing and protecting trees
- utilise pasture growing amongst trees for livestock production
- reduce competition between pastures/weeds and trees, and perhaps reduce the use of herbicides, and
- optimise tree growth.

4. Introductory technical information

Greater understanding of the factors influencing browsing of trees by sheep is necessary to develop appropriate management strategies. Anecdotal evidence from landholders and scientists suggests that the extent and severity of damage to trees browsed by sheep may vary with tree species and provenance, the size and age of individual trees, seasonal factors (including the availability and palatability of pasture on offer), and the breed, age and class of sheep.

In this project, components of a possible system that were investigated included:

- determining the natural variation in palatability of eucalypt species amongst sheep
- the ability of trees to recover from browsing
- the effect of tree height on browsing damage
- extent of browsing damage at different times of the year (ie. seasonal variation)
- the use of repellents to protect seedlings
- training sheep to avoid eating trees through conditioned food aversion (CFA).

Sheep browsing

It is commonly recognised that all sheep are not the same when it comes to browsing. There is often local information about what type of sheep will cause the least damage and when trees may be at greatest risk, but the differences are not well documented. Where they do exist, reports on the results of grazing trials are often divergent (Reid and Wilson 1985). In one New Zealand trial reported by Reid and Wilson (1985), different sheep breeds and Friesian calves were grazed, both in autumn and spring, amongst *Pinus radiata* trees. The sheep also differed in their previous experiences with trees. Perendales and Border Leicester X Romney Marsh hoggets caused the least damage while the calves severely browsed the trees.

In Western Australia, the general experience has been that cross-breeds and older sheep do more damage than pure breeds and young sheep. However tooth-ground old ewes can generally be grazed amongst young trees without causing damage (R.W. Moore pers. comm.). A rule of thumb for grazing amongst trees which has been advocated by some in the West is that the sheep should be half the age of the trees. For example, if the trees are 18 months old, the most suitable sheep would be lambs or young weaners; mature sheep are suitable only for older trees. There is ongoing debate about the accuracy of this 'rule of thumb'.

Anecdotal evidence in Victoria suggests that older sheep are less likely to damage trees than younger sheep. Young sheep appear more inquisitive and generally accept new foods more readily than adults, although by and large sheep are conservative feeders, preferring a known to a novel food when given a pair choice (Lynch *et al.* 1992). Prior experience also has a marked effect on diet selection; young lambs learn which foods to eat and avoid from their mothers and other adults at initial exposure, and this they will remember for many years.

Observations that browsing by sheep is greater in winter than spring or summer (eg. Anderson *et al.* 1985) suggests a possible connection between availability of roughage and browsing damage. Bird *et al.* (1995) measured sporadic damage to *Pinus radiata* trees from sheep in western Victoria. However they observed little pattern to the damage, although bark chewing and stripping occurred and was particularly severe during the spring of 1987. The relationship between changing availability and quality of pasture/tree foliage and sheep browsing is not well understood.

The grazing behaviour of sheep is complicated by the likelihood of individual preference or variation amongst the flock. 'Rogue' sheep with a particular attraction to tree seedlings may exist in any flock; management is unlikely therefore to completely eliminate the risk of browsing damage. The issue then becomes one of management to limit the damage (or perhaps identify the sheep in question and remove them from the flock), and what level of damage can the trees sustain before their growth or form is adversely affected.

Grazing management

The experiences of some farmers indicate that less tree browsing damage occurs when sheep are grazed at a higher stocking rate for a shorter period of time, than set stocked at a lower density. Anderson *et al.* (1985) observed less bark damage to pines when a large sheep flock was grazed in a big block for a few weeks rather than an extended period of grazing from a

smaller mob. They also measured less tree damage by alternating grazing between pastures with and without pines; over shorter rotational periods, the development of camp sites could be eliminated (the incidence of needle eating and bark stripping from pines was greater in sheep resting areas).

Observations that Travelling Stock Routes often contain good eucalypt regeneration, despite very high levels of intermittent grazing, led Curtis and Wright (1993) to propose a rotational grazing system to combine both animal production and tree regeneration on the Northern Tablelands of NSW. A form of Time Control Grazing which involves short, irregular bouts of intense grazing followed by rest periods to allow tree regrowth has been used successfully on the property of Tim Wright. The short period of grazing in each paddock has broken down sheep camp behaviour which can be detrimental to both tree seedling survival and health.

Tree species

Trees differ in their susceptibility to browsing damage by animals. Considerable local information and experience exists amongst landholders and advisers as to which species may be browsed preferentially, but little has been documented in the scientific literature. In contrast, there is a vast literature of the effects of livestock browsing poisonous native trees and shrubs.

Eucalypts appear to vary widely in their palatability to both wildlife and livestock. In Tasmania, *E. regnans* is more palatable than *E. obliqua* in their younger stages, both to native marsupials and to sheep and cattle (Anon 1979). *E. globulus* was much less palatable than both species when it was producing juvenile leaves. In a 1-year field trial in southern Victoria, Montague *et al.* (1989) compared 82 eucalypt species and provenances for relative browsing susceptibility to the swamp wallaby (*Wallabia bicolor*). The degree of browsing damage was scored using an arbitrary five point browsing index of 0-4.

There was large variation in the browsing damage between species with *E. paniculata* (mean score 3.75) and *E. teriticornis* (3.62) the most severely browsed species while *E. globulus* ssp. *maidenii* was the least browsed (0). Damage to *E. regnans* (0.1), *E. nitens* (0.15) and *E. globulus* (0.16) was minimal. *Pinus radiata* sustained major damage (2.65).

The length of time that a tree is susceptible to browsing is also dependent on its growth rate. On more favourable sites, trees may grow beyond the browsing height of sheep within 12-18 months, permitting safe grazing after this time. However many degraded areas requiring revegetation are less favourable for rapid (commercial) growth of trees and shrubs; in such cases, the risk from grazing sheep may persist for 4-5 years, or longer. For *Pinus radiata* (Bird *et al.* 1995) and rough-barked eucalypts and casuarinas (Bird pers. comm.), damage to trunks may persist for up to 10 years.

Recovery from browsing

The level of 'acceptable' damage to a tree is likely to vary with a number of factors including tree species, size of the tree and the timing and possibly, the distribution of damage. Partial defoliation on a single occasion is unlikely to affect the survival of eucalypts (Cremer 1968), but the trees will need an opportunity to re-leaf by removing the stock. In a study of browsing damage to plantation eucalypts by vertebrate herbivores, Montague *et al.* (1990) defined trees with less than 25% defoliation as 'undamaged'. However the authors did not provide information as to whether the growth rate of surviving trees was affected.

Neilsen and Pataczek (1991) have reported on the effect of simulated browsing on *E. nitens* and *E. regnans* seedlings. Moderate browsing caused significant reductions in growth and survival of both species with the effects lasting up to 3 years.

Repellents

The use of repellents (chemical or physical) to protect trees has been investigated for wildlife and vermin (eg. Crozier and Ledgard 1988; Sullivan *et al.* 1988; Montague *et al.* 1990), and to a limited extent for livestock. Reid and Wilson (1985) and Oates and Clarke (1987) report a number of repellents, including an animal fat/kerosene mixture and an egg/paint combination that have protected trees from sheep. These repellents and Thiropel spray concentrate (a Thiram-based product) also provided pine trees with protection from browsing by rabbits, hares and possums (Crozier and Ledgard 1988). According to Campbell (1991), there is potential for developing repellents which work by taste, smell or sound. However the use of repellents is complicated because herbivores learn to discriminate treated from untreated foliage, and repellents do not persist in plant tissues (F.D. Provenza pers. comm.).

Certain predator odours which may originate from faeces, urine or scent gland secretions elicit a 'fear' response when detected by prey species (Sullivan *et al.* 1988). Synthetic predator odours have been used successfully as repellents in several pest species in North America (Sullivan *et al.* 1988). In Australia, Montague *et al.* (1990) screened 15 potential repellents for protecting *E. regnans* from Swamp Wallaby. Repellents containing chilli or dog urine extract offered some protection from the browsing animals.

Many of the practical problems associated with repellents remain to be solved. Ideally, a repellent would be easily applied to the seedling just prior to planting out (and reapplied later as required), be inexpensive, non-toxic to either animal or the tree, long acting and be able to withstand the extremes of climate. However this is a demanding set of criteria.

Conditioned food aversion (CFA)

Livestock can be and are trained to eat certain foods. For example, sheep which have not previously encountered lupin grain must be trained to eat the grain which may take some time. This raises the question: Can livestock be trained to avoid eating desirable plant species such as trees?

The work of Prof. Fred Provenza (Utah State University, USA) and others over more than 15 years has shown that sheep, cattle and goats can be trained to avoid eating highly palatable foods in as little as 1 to 3 days. The aversion is developed by pairing the ingestion of the food with an emetic such as lithium chloride (LiCl) which causes nausea in the animals (Provenza *et al.* 1992). By associating the feeling of nausea with eating the particular plant, the animal develops an aversion to that food. The basis for this work to date has been to train animals to avoid eating poisonous plants, often freely available in the rangelands of western USA, but the possibilities exist also for averting animals from non-poisonous, desirable species.

The conditioned food aversion (CFA) can be established with dosages of LiCl as low as 150 mg/kg of body weight. Such a dose produces only mild nausea in the animal. Animal ethics questions may become important if higher dosages are used, causing the animal more discomfort.

Maintaining conditioned food aversions is not easy. Over time, the animals may sample foods that have been paired with LiCl. If the sampling does not provide aversive feedback, then animals increase their intake of the food (Provenza *et al.* 1992). The temptation to sample the food can be reduced if all animals in the flock or herd are trained to avoid the food and alternative food sources are available. To be useful practically, the aversion must persist in the animal in a complex vegetation community (Ralphs 1992).

One of the exciting possibilities of this work is that of averted mothers passing the aversion to their offspring through social learning (Ralphs 1992). This offers the potential to avert an entire social group through succeeding generations to certain foods which could include the foliage of (some) tree species.

5. Research Methodology

5.1 *The effect of height of tree seedling on sheep browsing*

It has been suggested that browsing damage to trees may be reduced by growing seedlings for longer in pots and planting out taller and therefore older trees (Montague pers. comm.). Grazing could then be introduced earlier to the paddock with less loss of grazing time and reduced damage to trees. However it is not known how long and to what height trees would need to be grown to achieve these objectives, other than being completely out of reach of the sheep. Two experiments were conducted to determine the importance of seedling height on browsing damage.

a) Ten trees of *Eucalyptus camaldulensis* covering 3 height ranges (0-50, 50-100 and 100-150 cm) were planted into each of 3 pasture plots measuring 30 x 30 m. The trees were spaced at 2 m apart with rows 5 m apart. Five weaner sheep were introduced to each plot and browsing damage to the trees was measured over the following 10 days.

b) The effect of height on browsing damage was also measured for 3 different eucalypt species (*E. camaldulensis*, *E. globulus globulus* and *E. maculata*) in a non-replicated trial. Ten seedlings of each species were planted out into an annual grass/sub.clover pasture and weaner sheep allowed access to the trees for a period of 2 weeks.

Browsing damage to the seedlings in both experiments was measured on a regular basis using a 6-point scale based on that described in Haines *et al.* (1994). The scale was:

- 0, seedling undamaged
- 1, 1-20% of seedling damaged
- 2, 21-40% seedling damaged
- 3, 41-60% seedling damaged
- 4, 61-80% seedling damaged
- 5, >80% seedling damaged.

5.2 *Sheep browsing preference amongst 18 tree species*

To assess the relative preference or palatability amongst sheep for eucalypt and acacia species, 16 eucalypt and 2 acacia species were compared in a field experiment. Tree species that are common in North-East Victoria and/or have potential as timber species in agroforestry systems were chosen for evaluation.

Seedlings of the 18 species (8 months old) were planted into 5 plots (replicates) measuring 30m by 30m; there were 4 trees/species/plot in a randomised block design. The trees were planted into an existing annual pasture. The rows were 3 m apart and the trees 2 m within the row.

Six weaner sheep were introduced into the plots in mid spring once the trees had survived transplanting. This gave a high stocking rate of about 80 DSE/ha (the average stocking rate in the region is 8-10 DSE/ha). The sheep were removed 1 week later. Over the experimental period browsing damage to the seedlings was assessed regularly using the 6-point damage scale described above. The quantity and quality of pasture on offer was determined at the start and the end of the experimental period by taking 10 quadrats (30 x 30 cm) randomly across each plot, drying and analysing for digestibility.

5.3 *Simulated browsing damage*

We were interested to determine whether some agroforestry species differed in their tolerance to, and recovery from, browsing damage, and whether timing of damage affected tree growth, survival and form. Species that are able to tolerate more browsing damage would be better suited to farming systems that aim to integrate trees and livestock production.

Five eucalypt species (*E. camaldulensis*, *maculata*, *sideroxylon*, *globulus globulus* and *melliodora*) were planted in groups of 5 trees and 10 browsing treatments were imposed; there were 3 replications of each treatment in a randomised complete block design. The trees were planted in early October 1994 following irrigation of the site to ensure adequate soil moisture during the prevailing drought conditions. The initial browsing treatments (1-6) were imposed within 3 weeks once the seedlings had successfully survived planting out. The second group of treatments (7-10) were imposed in April 1995 to seedlings that had received the same level of browsing damage in the previous spring.

The 10 treatments were developed from a similar study being conducted by Australian Paper Mills (APM) at Gippsland, Victoria, for high rainfall timber species (B.M. Jenkin, pers. comm.). The treatments aim to represent the range of browsing damage to plantation trees in Victoria that have been observed from browsing by wallabies and kangaroos. By using similar treatments, experimental design and measurements, the intention was to collect comparable data for medium and high rainfall areas of Victoria.

The simulated browsing treatments imposed were:

- 1, no browsing (control)
- 2, side branches partly browsed, apical tip not damaged (spring only)
- 3, apical tip browsed, side branches partly damaged (spring)
- 4, apical tip browsed, all side branches removed to leave a stick (spring)
- 5, apical tip and section of stem removed, bottom leaves remain (spring)
- 6, all foliage removed to leave a stub in the ground which is below the height of the last branches (spring)
- 7, side branches partly browsed, apical tip not damaged (spring and autumn)
- 8, apical tip browsed, side branches partly damaged (spring and autumn)
- 9, apical tip browsed, all side branches removed to leave a stick (spring and autumn)
- 10, apical tip and section of stem removed, bottom leaves intact (spring and autumn).

Tree survival and growth measurements were taken at regular intervals over a 2 year period.

5.4 Tree susceptibility to browsing damage at different times of the year.

There is anecdotal evidence to suggest that pressure on trees from browsing sheep is greater over winter when pasture availability and quality is low, or in spring when new tree growth is relatively palatable. However there is little quantified information to support these observations. We aimed to track sheep browsing damage to tree seedlings over a full year to determine if seasonal changes impact on the extent of browsing damage.

Seedlings of *Acacia melanoxylon* and *E. camaldulensis* were planted into rows spaced 2 m apart at one end in each of 3 field plots which measured 0.6 ha in area. The remainder of the plot area contained annual ryegrass/sub.clover pasture that had been established about 5 years previously. Sufficient numbers of tree rows were established to provide 2 new rows of trees containing up to 20 seedlings of each species to be exposed at 6 different grazing times throughout the year. A temporary fence that could be moved to expose new tree rows for each grazing period was erected. Eighteen cross-bred weaners were randomly allocated to the 3 plots, giving 6 sheep/plot. Plant samples were taken at the start of each trial to determine both the quantity and quality (digestibility) of available forage on offer.

For each grazing period, the sheep remained in the plots for up to 5 days. Browsing damage was assessed according to the 6 point browsing scale above. Assessment of browsing damage was initially performed twice daily and then daily once the rate of damage began to decline.

5.5 *The use of repellents to protect tree seedlings*

We aimed to determine the relative efficacy of a number of potential repellents for protecting seedlings from browsing sheep. Previous work by the principal investigator (Haines *et al.* 1994) had indicated that repellents derived from extracts of dog urine (supplied by T.L. Montague) and sheep dung offered short term protection to young seedlings in an intensive grazing situation. To evaluate a greater range of potential repellents more quickly, we conducted two-choice comparison experiments in the sheep house at Rutherglen to determine sheep preferences.

Six Merino wethers (3-4 years old; average liveweight 50.2 kg) were housed individually in metabolism cages in the sheep house and acclimatised to their environment over a 15 day period. They were fed a maintenance diet of ad lib chaffed ryegrass/sub.clover hay supplemented with mineral salts. Immediately prior to commencing each trial the sheep were fasted overnight to increase their appetite; the feeding trials commenced early the following morning.

The sheep were offered 2 buckets each containing 20 g of chaffed sub.clover/ryegrass hay. To the hay in one bucket was added 1 g (in the dry form) or 2mL (in the liquid form) of repellent which was mixed in thoroughly with the feed. This was the treated sample. The pair of feed buckets was presented to the sheep for a period of 1 minute.

At the end of this period, the buckets were removed and the feed remaining in each was weighed. This procedure was repeated 3 times for the same sheep/repellent combination with the position of the treated and untreated feed rotated each time so that the sheep would not associate bucket position with the preferred food on offer. Over the course of 3 days, feed treated with each of the 6 repellents was presented to all the sheep, giving a latin square experimental design of 6 treatments x 6 sheep with 4 replicates of each test.

5.6 Conditioned food aversion (CFA)

Research from the USA (eg. Provenza 1995) has shown the potential to modify the diet of animals by conditioning food preferences or aversions. Food aversions can be developed in as little as 3 days by linking the consumption of a particular food with administering an emetic (eg. lithium chloride) which induces nausea in the animal. The animal associates the feeling of nausea with the food eaten and reduces or eliminates future consumption of that food. We investigated the potential to condition an aversion to eating eucalypt seedlings, namely *Eucalyptus camaldulensis*, in sheep. The longevity of the aversion was evaluated in the complex field environment where the sheep had a wide choice of food including young *E. camaldulensis* trees.

i) *Conditioning the aversion:* Thirty-six yearling Merino wethers were divided into 2 treatments ('averted' and control) with 6 replicates; there were 3 sheep/group. The treatments were allocated randomly across the sheep house. Pens measured 4 x 4 m. A 10 day acclimatisation period followed with the sheep fed an ad lib diet of chaffed ryegrass/sub.clover hay supplemented with mineral salts. During this period the sheep were exposed to small quantities of tree leaves on 2 occasions to increase their confidence in sampling the food and to reduce the novelty of the food. Sheep are reluctant to eat foods that are unknown or novel to them.

The sheep were conditioned to avoid the *E. camaldulensis* leaves over a 5 day period. Each pen of 3 sheep was offered up to 10 branches (20 - 50 cm long, 0.5 - 1 cm in diameter) of *E. camaldulensis* which were harvested fresh from young trees planted nearby. The branches were inserted into a wooden frame 2 m in length so that they were erect and the sheep could easily smell and sample the food. Each pen was visually blocked from other sheep using black plastic around the perimeter. The sheep had been fasted the previous afternoon and evening to increase their appetite for the tree leaves. The consumption of eucalypt leaves by each sheep was assessed individually (1 observer/sheep) and recorded as the number of bites of tree leaves and the length of time browsing tree leaves over a 5 minute period.

Any sheep in the 'averted' treatment taking 1 or more bites of tree leaves during the pen trial were given a gelatin capsule containing the emetic lithium chloride (0.15g/kg live body weight), within 60 minutes of eating the eucalypt leaves. Sheep in the 'averted' group that failed to eat the leaves or mouthed but did not ingest the material and those in the control group were all given an empty gelatin capsule using a balling gun. The sheep were fed ad lib hay at least 3 hours after treatment with LiCl. This procedure continued for 5 days until all the sheep in the treated pens were averted (ie. had sampled the leaves, been given LiCl and then not consumed the tree leaves again).

ii) *Field testing the aversion:* The effectiveness and longevity of the aversion was tested over time in small field plots containing a range of forage species and young trees. The same groups of 3 sheep were placed into plots measuring 15 x 15 m containing ryegrass/sub.clover pasture and about 25 *E. camaldulensis* trees 12-18 months old. Small branches from these trees had been used to condition the aversion in the sheep house. The sheep were placed in the plots following a period of grazing in a nearby pasture paddock; there was no access to eucalypt trees in this paddock.

The plots were visually separated from each other with shade cloth to prevent averted sheep from learning feeding behaviours from the control sheep. To measure whether the sheep were browsing the trees, observations were taken of each sheep every 15 s for 2 hours using the scan technique developed by Altmann (1974). There were 3 categories of activity observed and recorded:

- a) browsing tree
- b) grazing pasture
- c) resting

The sheep were then returned to the adjoining pasture paddock and allowed to graze until the process was repeated some weeks later. This process continued for some months to gauge the effectiveness of the conditioning process over time and in changing field conditions.

5.7 Statistical analyses

Data for the various experiments were analysed using GENSTAT 5. Analysis of variance (ANOVA) was generally applied to the data to determine significant differences between treatments. For the experiment on the effect of tree height on browsing damage, linear regression was used to model progressive defoliation of the seedlings.

6. Results and Discussion

6.1 The effect of height of tree seedling on sheep browsing

a) The taller trees generally suffered less browsing damage than the shorter seedlings ($P < 0.05$) over the experimental period, although the relationship between damage and height as described by the regression equation was poor (r^2 ranged from 0.10 to 0.41). In addition to being taller and therefore further away from the grazing focus of the sheep, the larger trees usually had more leaves and were more likely to tolerate moderate levels of browsing damage without significant effect on survival or growth rate. None of the trees was totally out of reach of the sheep grazing the plots.

b) The mean height of *E. maculata*, *E. globulus globulus* and *E. camaldulensis* at the start of the trial was 74.1, 48.9 and 108.4 cm respectively. Over the period of the experiment, *E. globulus globulus* was the least damaged but was the shortest of the 3 species. *E. camaldulensis* was the tallest species but along with *E. maculata* sustained the most browsing damage, indicating that relative species attractiveness or palatability was a more important factor in the propensity of sheep to browse than the height of the seedling. Both *E. maculata* and *E. camaldulensis* were well within the browsing height of the sheep to sustain considerable damage. The sheep selected plant material based on a combination of olfactory, taste cues and postingestive feedback. Collectively this can be referred to as palatability.

As a general strategy, planting slightly older and taller seedlings (perhaps grown for 6-9 months longer in the tube stage) could reduce browsing damage. The trees are likely to be well above the browsing height of the animals within a shorter period and could tolerate more damage than small seedlings. This would allow earlier grazing by sheep amongst trees and make better use of any available forage. However using taller and older seedlings may increase stress at planting out due to the larger above ground biomass relative to the root system. The roots may be inadequate to support the seedling which could result in increased mortality, particularly if the soil dried out soon after planting. Larger tubes to allow for greater root development may be required to support the bigger seedling.

6.2 Sheep browsing preference amongst 18 tree species

The trees were continually exposed to browsing pressure at a high stocking rate over a 6-day period. At the commencement of the experiment available forage in the 5 replications ranged from 2400 to 3100 kg/ha (mean 2600 kg/ha). With the reduction in pasture forage with the high stocking rate and increased soiling of remaining forage by urine and faeces, the pressure on the trees increased the longer the experiment continued.

By the first assessment on day 1, the mean browsing damage was low (0.8, 0-5 scale) but there was significant variation ($P < 0.05$) in damage across the range of species (Table 1). While damage to *Eucalyptus globulus globulus*, *E. globulus bicostata*, *E. viminalis*, *E. maculata* and *E. polyanthemos* was minimal (< 0.2), moderate damage had occurred for *E. camaldulensis* (Hindmarsh), *E. melliodora* and *Acacia melanoxylon* (range 2.2-2.3 mean damage). This suggested that although there was adequate pasture forage of good quality on

offer, from early on the sheep were actively selecting certain tree species for 'testing' while others were largely ignored or rejected.

Table 1. Browsing damage to 18 tree species by weaner sheep

Species	Time 1	Time 2	Time 3	Time 4	Time 5	Time 6
<i>E botryoides</i>	0.9	1.6	1.7	2.6	2.9	4.1
<i>E camaldulensis</i> . Hindmarsh	2.2	3.1	3.5	3.8	4.1	4.2
<i>E camaldulensis</i> . Ovens	1.1	2.2	2.5	3.3	4.1	4.5
<i>E cladocalyx</i>	0.4	1.4	1.5	2.2	2.5	3.5
<i>E globulus bicostata</i>	0.1	0.6	0.8	0.9	1.1	2.1
<i>E globulus globulus</i>	0.2	0.5	0.7	1.2	1.7	2.5
<i>E macrorhyncha</i>	0.6	1.2	1.7	2.6	2.9	3.8
<i>E maculata</i>	0.2	0.2	0.2	1.2	1.6	2.3
<i>E melliodora</i>	2.3	3.4	3.7	3.9	4.0	4.3
<i>E microcarpa</i>	0.6	1.0	1.3	2.1	2.6	3.3
<i>E nitens</i>	1.2	2.3	3.0	3.9	4.3	4.9
<i>E obliqua</i>	0.5	1.0	1.3	1.9	2.3	3.5
<i>E polyanthemus</i>	0.2	0.5	1.0	1.5	1.9	3.7
<i>E regnans</i>	0.5	0.8	1.1	2.2	2.5	3.4
<i>E saligna</i>	0.8	1.8	1.9	2.7	3.4	4.2
<i>E viminalis</i>	0.2	0.8	0.9	1.8	2.0	3.5
<i>A dealbata</i>	1.3	2.6	2.9	3.5	3.9	4.3
<i>A melanoxylon</i>	2.2	2.9	3.4	4.2	4.3	4.8
lsd ($P < 0.05$)	0.8	0.8	0.8	1.0	1.0	0.8

Browsing damage continued in a relatively linear pattern for most species so that by the end of day 2, the mean browsing damage had increased to 2.5 with damage to *E. globulus bicostata*, *E. globulus globulus* and *E. maculata* minimal (range 0.9-1.2), but significant damage had occurred to *E. camaldulensis* (both provenances), *E. melliodora*, *E. nitens* and *A. melanoxylon* (range 3.3-4.2). By day 3 the range in damage for the least preferred group above had increased (1.1-1.6) but was still significantly less ($P < 0.05$) than the more palatable group (range 4.0-4.3).

After 1 week of exposure to the weaner sheep and with available forage reduced by the high stocking rate, the mean damage for all species was becoming severe (3.7). However while *E. nitens*, *E. camaldulensis*, *E. melliodora* and both acacia species had all but been destroyed by browsing, *E. globulus bicostata*, *E. globulus globulus* and *E. maculata* had suffered only moderate damage (mean 2.9), indicating that the initial likes and dislikes of sheep for certain species were maintained throughout a lengthy period of sustained browsing pressure. In a real grazing system, it would be preferable to remove the sheep well before damage reached such a level. However if less palatable species were planted, there is a greater margin for error in management which would not result in complete destruction of the seedlings.

These results indicate that considerable variation exists amongst the eucalypts in their palatability to sheep. Possums and wallabies have been shown previously to prefer certain tree species and concentrate their feeding on those species but this is the first study conducted for livestock. It has been suggested that the presence of some oils, particularly cineole, in the leaves of eucalypts may be an anti-feedant to herbivores. The level of cineole in species such

as *E. globulus* is relatively high. However recent zoological studies at James Cook University, Townsville, have identified a new class of natural compound in eucalypts that is a potent anti-herbivore defence, active against mammals and insects. Some eucalypt genotypes contain high concentrations of this compound whereas others (even within the same species) are poorly protected. The deterrent compounds are not volatile terpenes such as cineole which have been shown to possess little antifeedant activity (W.J. Foley, pers. comm.). It may well be that cineole is a cue for the presence of other compounds which are unpalatable.

With the selection of tree species known to be less attractive or palatable to sheep and with careful on-going management, it would be feasible to integrate sheep grazing with tree growing without suffering excessive damage to trees. On-farm planting may spatially separate species known to be more palatable for more intensive protection. Species that are less at risk could be grown in a more integrated system with pasture and livestock without the same level of protection. Such a system would need to be carefully monitored to ensure the level of damage was such that the tree was not adversely affected.

6.3 Simulated browsing damage

Seedling survival of the 5 species after 22 months where no simulated browsing was imposed ranged from 93% for *E. sideroxylon* to 100% for *E. melliodora*. Although the seedlings were planted during the drought of 1994, an initial irrigation of the site and excellent ongoing weed control ensured the trees had every opportunity to establish and optimise their growth.

Simulated browsing did not affect seedling survival except for the most severe treatments imposed (treatments 6, 10 and 11). Treatment 6 (removal of all plant material to leave a stub in the ground) caused mortality up to 100% (*E. globulus*) but had no effect on the survival of *E. melliodora* survival. Repeated, severe browsing (treatment 10) reduced survival of *E. sideroxylon* and *E. maculata* to 53% and 60%, respectively. In terms of survival, of the 5 species evaluated, *E. camaldulensis* and *E. melliodora* were the most tolerant of browsing damage.

At planting, tree height ranged from 13 cm (*E. maculata*) to 43 cm (*E. globulus*). Six months after planting, the height of the unbrowsed trees ranged from 81 cm (*E. sideroxylon*) to 124 cm (*E. camaldulensis*). Modest browsing of the apical tip and side branches (treatment 3) soon after planting had no effect on tree height with all species recovering from the initial setback, while more severe browsing damage significantly ($P < 0.05$) reduced the growth of *E. camaldulensis*, *E. melliodora* and *E. maculata*. Only the most severe browsing (treatment 6) affected the height of *E. globulus* and *E. maculata*.

Fourteen months after planting and seven months after the imposition of the repeated browsing treatments, treatments 9 and 10 had reduced the heights of all species compared with the control (Table 2). The mean height of the trees following these treatments was reduced by 35% and 53%, respectively. *E. melliodora* recovered from the removal of all leaf material during the first spring.

Table 2. Height (cm) to age 14 months of 5 eucalypt species subjected to various browsing treatments

Species	Treatment									
	Control	2	3	4	5	6	7	8	9	10
<i>E. globulus</i>	247	272	232	230	226	0	244	236	192	142
<i>E. camaldulensis</i>	174	200	166	146	132	107	186	166	127	108
<i>E. sideroxylon</i>	134	146	130	120	115	52	126	127	83	67
<i>E. melliodora</i>	127	127	120	93	118	100	115	104	90	62
<i>E. maculata</i>	157	162	108	99	79	129	102	108	60	27

lsd ($P < 0.05$) 42.7

Fifteen months following simulated browsing, only the most severe treatments (6 and 10) were still having an effect on the height of the trees, although *E. maculata* was affected by less severe browsing (Table 3). There was no difference in height amongst *E. melliodora* trees for any of the simulated browsing treatments.

Table 3. Height (cm) to age 22 months of 5 eucalypt species subjected to various browsing treatments

Species	Treatment									
	Control	2	3	4	5	6	7	8	9	10
<i>E. globulus</i>	368	429	360	393	351	0	401	376	315	257
<i>E. camaldulensis</i>	247	268	243	215	180	168	261	235	184	189
<i>E. sideroxylon</i>	193	207	183	181	198	88	192	188	131	72
<i>E. melliodora</i>	172	164	166	125	163	123	153	145	137	103
<i>E. maculata</i>	254	243	194	168	146	231	155	189	82	60

lsd ($P < 0.05$) 73.8

Browsing did not affect the survival of the seedlings of the 5 species unless severe. Treatments imposed soon after planting that caused partial defoliation and damage to the apical tip generally did not affect tree height at 2 years of age. More severe damage that was repeated in the following autumn caused some reduction in growth rates particularly for *E. maculata*. *E. globulus* and *E. melliodora* recovered better from the early setback than the other species and may be more tolerant to browsing.

6.4 Tree susceptibility to browsing damage at different times of the year

The susceptibility of seedlings of *E. camaldulensis* and *A. melanoxylon* to browsing was assessed at different times of the year. With changing seasonal conditions, the quality and quantity of available forage varies which may result in nutritional gaps in the diet of sheep. Also physiological changes in the tree itself may increase or decrease its relative attractiveness to sheep over the year. Understanding when the tree is more at risk from browsing livestock can assist in planning appropriate management strategies.

Seedlings of both species were browsed more quickly during March just prior to the autumn break when forage was becoming limited and low in quality than in May and July when feed was more plentiful (Table 4). Damage to *A. melanoxylon* seedlings was severe within 1 day of the sheep being introduced to the plots in March; *E. camaldulensis* sustained modest damage relatively quickly compared to grazing in May and July. Irrespective of the amount or quality of feed available both tree species had suffered extensive damage by day 3 of the experiment with *A. melanoxylon* almost completely destroyed.

Table 4. Browsing damage to *E. camaldulensis* and *A. melanoxylon* seedlings at different times of the year

Season		<i>E. camaldulensis</i>	<i>A. melanoxylon</i>
March	Day 1	1.1	4.3
	Day 2	1.4	4.5
	Day 3	3.5	5

	Day 4	4	5
May	Day 1	0.1	0.9
	Day 2	2	2.9
	Day 3	3.3	4.7
	Day 4	4.2	4.8
July	Day 1	0.7	3.2
	Day 2	1.4	3.9
	Day 3	2.5	4.3
	Day 4	4.2	5

Although it has been suggested that trees sustain more damage in winter when pasture is 'sappy' and livestock may lack fibre in their diet, our results generally do not support this view. The experiment will continue until the year of 1996 (beyond the life of the project) so that a more comprehensive understanding of the effect of time of year on browsing damage can be determined. This will cover the spring and summer periods.

6.5 *The use of repellents to protect tree seedlings*

A pilot trial was undertaken to establish the most appropriate experimental procedure to test potential repellents and to evaluate the efficacy of 6 repellents. The repellents tested were: old formulation of Replex 1 or 'old' Replex 1 (see Haines *et al.* 1994), new formulation of Replex 1 or 'new' Replex 1, Replex 6, 7 and 8, and sheep dung. Of these, Replex 6 and 7 were found not to be effective and were dropped from further testing; the rest were used in the main experiment. Replex 3 and 5 were included for the main choice test.

In a simple 2-choice test (untreated v's treated feed), the consumption by sheep of hay treated with each of the 6 repellents was significantly less than that of the untreated control (Table 5). The average amount of untreated hay eaten during the 1 minute trials was 8.3 g (41% of hay on offer) and for the treated hay was 0.35 g (1.7% of hay on offer). However of the 6 repellents evaluated, sheep dung, old and new Replex 1, Replex 3 and 5 were the most effective while Replex 8 was less effective, in relative terms.

Table 5. The amount of repellent-treated and untreated feed remaining following grazing by sheep for 1 minute

Repellent	Treated feed remaining (20g)			Untreated feed remaining (20g)		
'Old' Replex 1		19.5			12.1	
'New' Replex 1		20			11.4	
Replex 3		19.9			11.8	
Replex 5		20			10.3	
Replex 8		18.5			12.8	
Sheep dung		20			11.9	
lsd ($P<0.05$)		0.77			ns	

The above results suggest that sheep respond to a number of compounds from simple sheep dung through to formulations based on dog urine, from which the Replex series of chemicals were formulated. The application of these compounds to a palatable food such as hay greatly reduced consumption in a simple paired comparison. The sheep quickly identified those odours that were 'unpleasant' and generally only ate the untreated food. By rotating the position of the bucket containing the treated food, the sheep had to make a decision each time about which feed bucket to eat from.

The aim of this component of the project was to compare potential repellents that had been developed elsewhere for different 'pest' species and test their efficacy with sheep. We had shown previously (Haines *et al.* 1994) in more complicated field testing that repellents can reduce damage to trees in the short term but long term protection is most unlikely. This is because the active ingredient of many repellents is volatile and may not persist for long on the seedlings when exposed to the prevailing climatic conditions. Also herbivores quickly learn to discriminate treated from untreated foliage which exposes new growth to potential damage.

The longevity of repellents will be enhanced if the animals experience an unpleasant response or negative post-ingestive feedback from eating the treated foliage. That is, the leaves not only smell bad (olfactory cue) but they are unpleasant to eat. Such feedback will reinforce in the animal the dislike for the material and reduce subsequent consumption. Since the repellents that we had available for testing were based on an olfactory response alone, further testing was not undertaken and increased emphasis on training sheep to avoid eating trees by conditioning an aversion (see below).

6.6 Conditioned food aversion

i) *Conditioning the aversion:* The sheep were conditioned to avoid eating *E. camaldulensis* leaves within a few days in the sheep house. On day 1 of the conditioning, in the 5-minute period of measuring intake of tree leaves, the sheep averaged 117 bites each (mean of treated and untreated groups). Following treatment with LiCl of the sheep in the 'averted' group which ate tree leaves, mean bites on day 2 for this group decreased to 2 bites/sheep compared to 190 bites/sheep for the control group (Table 6). On day 3 the 'averted' sheep did not eat any tree leaves while the control group averaged 86 bites/sheep. However some sheep in the 'averted' group had not sampled the tree leaves and therefore had not been treated with LiCl. The experiment was continued for a further 2 days to ensure all sheep in the 'averted' group had sampled the trees and were therefore conditioned. In summary, the sheep had quickly

and effectively been conditioned to avoid eating tree leaves even though they were hungry, having been fasted overnight and with no alternative food on offer during the experiment.

Table 6. Number of bites of *E. camaldulensis* leaves (over 5 minutes) for untreated and conditioned averted sheep

Treatment	Day 1	Day 2	Day 3	Day 4	Day 5
Untreated					
Rep 1	93	161	53	45	128
2	74	146	0	102	96
3	98	230	85	66	116
4	227	210	128	182	144
5	202	210	158	197	199
6	102	182	94	202	141
mean	133	190	86	132	137
Conditioned					
Rep 1	120	0	0	8	0
2	101	0	0	4	0
3	69	7	0	0	0
4	34	0	0	0	0
5	115	3	0	45	0
6	173	4	0	0	3
mean	102	2	0	9	0.5
lsd (P<0.05)	ns	40.8	41.2	55.6	46.1

ii) *Field testing the aversion:* To test the longevity of the conditioned aversion and determine whether it would persist in a more complex environment, 10 field evaluations were performed over a 5 month period. During the period of testing, there were changes in the availability and quality of pasture on offer; from the peak spring flush to early summer when feed was less plentiful.

The level of tree browsing by the sheep from the control treatment throughout the experiment was negligible (Table 7). Even when there was little pasture on offer and quality was decreasing, the sheep virtually ignored the trees which were scattered evenly across the plots. They compensated for the relative lack of feed by grazing the pasture for longer. On 2 occasions, the averted sheep ate significantly less tree material than the untreated sheep. However the level of browsing by both groups of sheep was minimal which made it difficult to fully evaluate the effectiveness of the conditioned aversion.

Although young sheep, which previous work had shown to be more likely to sample the trees, were used for the conditioned aversion experiment, it may have been preferable to use cross-bred rather than Merino sheep. At the time of the experiment, only Merino sheep were available to the project.

Table 7. Number of bites of pasture and *E. camaldulensis* leaves by untreated and conditioned averted sheep over 5 months

Treatment	Time 1	Time 2	Time 3	Time 4	Time 5	Time 6	Time 7	Time 8	Time 9	Time 10
Eating trees										
untreated	4.9	0.3	3.1	1.3	0.3	0.8	0.2	1	1.3	1.1
averted	0.7	0.1	0.7	0.1	0	0.1	0.1	0	0.8	1.3
lsd (P<0.05)	ns	ns	ns	1.1	ns	0.6	ns	ns	ns	ns
Eating grass										
untreated	191.6	216.7	146.8	215.9	168.5	220.1	215.7	218.4	196.1	224.1
averted	148.8	209.5	147.8	210.7	162.8	221.3	211.7	199.5	178.1	227.5
lsd (P<0.05)	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

To increase the attractiveness of the trees to the sheep (and thereby put increased pressure on the conditioned aversion), the plots were grazed with non-experimental sheep just prior to some of the experiments to decrease the pasture on offer and make it less attractive. Even with such management the sheep did not show increased interest in the trees and the level of tree browsing remained low

To retest the aversion in a more controlled environment, the sheep were returned to the sheep house. Following overnight fasting, the sheep were presented with a selection of fresh *E. camaldulensis* branches from the plots that they had previously grazed. The consumption of leaves by the control group was significantly higher than for the 'averted' group for the 2 days that both groups were compared (Table 8). The aversion had persisted over the 3 months that the sheep had been grazing in the field with regular exposure to young trees.

By day 2, the consumption of tree leaves by the 'averted' group had increased substantially although it was still less than the untreated sheep. This indicated that with overnight fasting, the sheep had been 'encouraged' to sample the tree leaves. Since there was no negative postingestive feedback from this experience (ie. the sheep were not re-averted), the sheep increased their consumption of the tree leaves.

For tests carried out on days 3-6, sheep from the 'averted' group that ate the tree leaves were reconditioned with lithium chloride. This resulted in the sheep decreasing consumption of tree leaves from day 3 up to day 6, although complete aversion of all sheep was not obtained.

Table 8. Number of bites (over 5 mins.) of *E camaldulensis* leaves by untreated and conditioned averted sheep, 3 months after initial conditioning

Treatment	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6
Untreated						
Rep 1	140	147	na	na	na	na
2	76	90	na	na	na	na
3	143	168	na	na	na	na
4	209	258	na	na	na	na
5	224	190	na	na	na	na
6	207	283	na	na	na	na
mean	166	189	na	na	na	na
Conditioned						
Rep 1	34	67	45	48	4	1
2	19	48	49	29	0	2
3	0	187	134	58	0	1
4	25	96	64	17	0	10
5	4	68	740	12	15	44
6	25	49	21	0	58	2
mean	18	86	64	27	13	10
lsd (P <0.05)	35.9	54.9	na	na	na	na

7. Implications and Recommendations

The ongoing loss of native vegetation from Australian farms is a significant environmental problem. The landscape of many farms is changing dramatically as mature eucalypt trees die out with few young trees to replace them. The past decade has seen much activity by landholders in planting trees for land protection and increasingly, (timber) production reasons. However the need to protect young trees from grazing animals with expensive fencing limits the amount of revegetation undertaken. Alternative strategies that manage rather than totally exclude livestock, particularly sheep, from revegetation and agroforestry areas are required to accelerate the pace of revegetation.

This research project has sought to better understand the impact of sheep browsing on trees, what species of trees are most at risk and when, and develop alternative strategies for reducing browsing damage. Novel approaches that include the use of repellents and conditioned food aversion have been assessed for their potential to 'swing the balance' toward the tree. Whereas most approaches including fencing and repellents focus on protecting the 'at risk' seedling, conditioned food aversion aims to modify the behaviour of the sheep to make the tree unattractive and unpalatable. The project demonstrated that sheep can be conditioned to avoid eucalypt trees relatively easily and the aversion can persist for some time in the complex field environment. This component of the work requires further investigation and development.

The project has pursued an integrated solution to sheep grazing amongst young trees. It is most unlikely that there will be a simple and complete answer. An appropriate strategy may involve growing trees that are less palatable (although in the case of key agroforestry species such as *Pinus radiata* which are palatable this is not possible) and are more able to recover

from browsing damage, ensure optimum weed control so that the tree can grow quickly and be out of reach of the sheep, use repellents applied for short term protection during times of the year when the trees are more at risk, and modifying sheep behaviour to make young trees less palatable and attractive. Although this approach places a greater emphasis on management and the skills of the landholder, the benefits from reduced fencing and increased revegetation may be substantial. There are still areas requiring further research and development if landholders are to have the confidence to 'pull down the fences' (or not to erect permanent fences in the first place).

Future research programs need to:

- emphasise the importance of post-ingestional feedback in developing aversions to key tree species. Unless the animals receive feedback that the food is unpleasant (and perhaps poisonous), they will continue to increase their consumption of the plants until they are satiated or the level of toxins reaches a threshold. Preventing animals from sampling foods they have been trained to avoid is the major challenge to successfully maintaining aversions in livestock. Repellents that rely on olfactory cues alone are unlikely to provide more than short term protection.
- continue to focus on an integrated solution to the browsing of young trees. There is unlikely to be a single answer that offers complete protection for young trees while allowing grazing of adjacent pasture. An integrated solution may include growing trees that are less palatable to stock, are better able to recover from browsing damage, fast growing species so that they quickly grow above the browsing height and aversive conditioning to cause a hedonic shift in palatability of the trees.
- isolate and identify the major chemical anti-feedants in the less palatable species that confer a degree of protection from browsing. Methods that can rapidly identify these constituents could be employed to test a range of species and provenances. Future tree breeding may incorporate genes for anti-feeding into agroforestry species to permit grazing amongst young trees from the earliest possible age.

8. Intellectual property

The repellents formulated and supplied by T.L. Montague Pty. Ltd. (the Replex series) remain the property of that company. There are no other intellectual property issues arising from the project.

9. References

Altmann, J. (1974). Observational study of behaviour: sampling methods. *Behaviour* **49**, 227-67.

Anderson, G.W., Hawke, M. and Moore, R. W. (1985). Pine needle consumption and bark stripping by sheep grazing annual pastures in young stands of widely spaced *Pinus radiata* and *P. pinaster*. *Agroforestry Systems* **3**, 37-45.

Anon (1979). Eucalypts for Planting. Food and Agriculture Organisation, Forestry Series No. 11.

Bird, P. R., Kellas, J.D., Kearney, G.A. and Cumming, K.N. (1995). Animal production under a series of *Pinus radiata*-pasture agroforestry systems in south-west Victoria, Australia. *Australian Journal of Agricultural Research* **46**, 1299-1310.

Campbell, C.A. (1991). 'Planning for Sustainable Farming - the Potter Farmland Plan Story'. (Lothian Books: Melbourne.)

- Campbell, C.A. (1993). Can Australian farming systems be more sylvan? *Agroforestry Systems* **22**, 17-24.
- Cremer, K.W. (1968). Browsing of mountain ash regeneration by wallabies and possums in Tasmania. *Australian Forestry* **33**, 201-10.
- Crozier, E. R. and Ledgard, N.J. (1988). Animal repellents for tree seedlings. *What's-New-in-Forest-Research* **162**, 1-4.
- Curtis, D. J. and Wright, T. (1993). Natural regeneration and grazing management - A case study. *Australian Journal of Soil and Water Conservation* **6**, 30-4.
- Edwards, P.B., Wanjuru, W.J. and Brown, W.V. (1993). Selective herbivory by Christmas beetles in response to intraspecific variation in Eucalyptus terpenoids. *Oecologia* **95**, 551-7.
- Haines, P.J., Bell, A.B. and Thatcher, L.P. (1994). Evaluation of some factors involved in reducing browsing damage to eucalypt trees by sheep. *Australian Journal of Experimental Agriculture* **34**, 601-7.
- Lynch, J.J., Hinch, G.N. and Adams, D.B. (1992). The behaviour of sheep - biological principles and implications for production. (CAB International and CSIRO Publications, Vic.)
- McKellar, H. (1993). Establishing trees under browsing conditions. *Tree Grower* November 1993, p. 14.
- Montague, T.L., Cameron, J.N., Appleton, R. and Krygsman, M. (1989). Variation between Eucalypt species with respect to browsing damage. National Afforestation Program, Technical Report 89/2 (Project 50).
- Montague, T.L., Pollock, D.C. and Wright, W. (1990). an examination of the browsing animal problem in Australian eucalypt and pine plantations. *Proceedings of the Vertebrate Pest Conference* **14**, 203-8.
- Neilsen, W.A. and Pataczek, W. (1991). Effect of simulated browsing on survival and growth of Eucalyptus nitens and E. regnans seedlings. *Tasforests* **3**, 41-6.
- Prinsley, R.T. (1991). Australian agroforestry -m setting the scene for future research. (Rural Industries Research and Development Corporation: Barton, ACT.)
- Provenza, F.D. (1995). Postingestive feedback as an elementary determinant of food preference and intake in ruminants. *Journal of Range Management* **48**, 2-17.
- Provenza, F.D., Pfister, J.A. and Cheney, C.D. (1992). Mechanisms of learning in diet selection with reference to phytotoxicosis in herbivores. *Journal of Range Management* **45**, 36-45.
- Oates, N. and Clarke, B. (1987). 'Trees for the Back Paddock'. (Goddard and Dobson: Box Hill, Vic.)
- Ralphs, M.H. (1992). Conditioned food aversion: Training livestock to avoid eating poisonous plants. *Journal of Range Management* **45**, 46-51.
- Reid, R. and Wilson, G. (1985). 'Agroforestry in Australia and New Zealand'. (Goddard and Dobson: Box Hill, Vic.)

Sullivan, T.P., Sullivan, D.S., Crump, D.R., Weiser, H. and Dixon, E.A. (1988). Predator odours and their potential in managing pest rodents and rabbits. *Proceedings of the Vertebrate Pest Conference* **13**, 145-50.

10. Appendices

i) Articles and conference proceedings from the Project

Haines, P.J. (1994). 'Don't fence me out'- The search for livestock grazing management options amongst trees. *Faces of Farm Forestry Conference* (Australian Forest Growers, Launceston). pp. 185-90.

Haines, P.J. (1994). The issue ... fencing. The problem ... costs. *Bush Chronicle*, August 1994, No. 51.

Haines, P.J. (1995). Livestock grazing options amongst trees. *Trees and Natural Resources* September 1995. pp. 22-26.

Haines, P.J. (1995). Integrating livestock grazing with tree growing. A report of agroforestry research in northeast Victoria. *Trees for Profit Workshop*, Shepparton, July 1995.

Haines, P.J. (1996). Tree grazing damage can be prevented. *Farming Ahead*. January 1996. p.43.

ii) Refereed publications

Haines, P.J., Bell, A.B. and Thatcher, L.P. (1994). Evaluation of some factors involved in reducing browsing damage to eucalypt trees by sheep. *Australian Journal of Experimental Agriculture*, 34: 601-7.

Haines, P.J. and Wilson, K. (199_). The effect of simulated browsing on the survival and growth of seedlings of 5 *eucalyptus* species. *Australian Journal of Experimental Agriculture* (in prep.)

Haines, P.J. and Wilson, K. (199_). Conditioning an aversion in sheep to *E. camaldulensis* seedlings. *Applied Animal Behaviour Science* (in prep.)