Ecologically Sustainable Agriculture Initiative

Protection of threatened species in agricultural landscapes
Flora Species Final Report:

Cullen parvum F. Muell. (Small Scurf-pea)

Photo: John Eichler

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March 2005

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Executive Summary

Grazing intensity, selection and season of grazing influence the composition of grazed grasslands. In native pastures inter-tussock forbs are often highly palatable and can be susceptible to intensive herbivory. It is argued that under set-stock grazing systems, grazing animals are able to selectively forage, leading to alterations in the competitive hierarchy between plant species and particularly to a decline and eventual loss of palatable species. Alternative grazing systems using high densities of animals for short durations are thought to reduce selective grazing, favouring persistence of palatable species. By using the grazing analogue treatment of clipping and trampling, the responses of the native legume, *Cullen parvum*, to selective, non-selective and season of grazing was investigated.

Results suggest that *C. parvum* will probably be favoured by simple deferred grazing strategies that minimise grazing damage through the growing season and maintain surrounding vegetation biomass. Results also suggest that grazing early in the growing season (eg. resting from late spring to late summer) may be preferable to late summer or multiple grazing events throughout the growing season. However, the long-term persistence of this species under any grazing regime is unknown, with results from this study indicating that ungrazed plants have greater growth and inflorescence production than grazed plants.

General Introduction

"Threatened Species and Farming" is a sub-project within the Ecologically Sustainable Agriculture Initiative (ESAI) undertaken by the Department of Sustainability and Environment and the Department of Primary Industries. This project addresses how agricultural practices might be modified to help conserve selected threatened species as part of working toward ecological sustainability. The project documents case studies of selected threatened species in four bioregions: the Victorian Riverina, Wimmera, Victorian Volcanic Plain and Gippsland Plain. The farms considered include examples from the meat, wool, dairy and grains industries. This case study focuses on the Small Scurf-pea (*Cullen parvum*).

Native vegetation cover in south-eastern Australia has been significantly modified since European settlement, primarily to develop land for agricultural production (NLWRA 2001). In fertile, high rainfall landscapes, remaining native vegetation often persists as small isolated patches and, in the case of once wooded landscapes, as scattered paddock trees. For example in the Victorian Volcanic Plains as little as 1% of native grassland remains (NRE 1997). The maintenance of native vegetation cover in these agricultural landscapes is important for the persistence of native biodiversity, reducing land degradation, providing shelter and drought fodder for livestock.

In this report we outline a research case study undertaken on *Cullen parvum* in livestock production systems in southern Victoria. The case study highlights issues regarding the management of native vegetation in southern Australia. The study considers the role of grazing frequency and selectivity in determining the persistence of perennial native legumes, a functional group which has apparently been most impacted by grazing management in grassy vegetation.

Introduction

Ungulate herbivores can modify the composition of grassy vegetation through direct grazing and trampling as well as indirectly through modifications to competitive hierarchies, changes in soil structure and composition. Relative preference for different plant species and the frequency of herbivory are thought to be two primary factors, that influence changes in vegetation composition partly due to modifications in competitive hierarchies within the plant community. Several studies have also demonstrated that processes that influence seedling recruitment are also important determinants of species persistence or extinction in grazed grasslands.

In native grassland ecosystems, inter-tussock forbs are often palatable to domestic livestock and thus susceptible to grazing impacts (Leigh and Holgate 1978, Wimbush and Costin 1979, Leigh *et al.* 1991, Lynch *et al.* 1992, Bridle and Kirkpatrick 2001, Dorrough and Ash 2004). Plant species differ in their relative selection by grazing animals. Factors such as palatability, energy reserves, secondary plant compounds and accessibility influence plant selection. Selectivity of plant species will also vary with season, plant life-history stage (seedling versus adult) and relative pasture composition. Selective grazing of particular species can alter competitive hierarchies in the pasture and hence pasture composition. Intensive rotational grazing management strategies reduce animal preference and so are thought to maintain palatable species.

Grazing intensity and season of grazing also influence the composition of grazed grasslands. The timing of grazing can influence the growth, fecundity and survival of plant species (Hodgkinson *et al.* 1989, O'Connor and Pickett 1992, FitzGerald and Lodge 1997, Ash and McIvor 1998, Bridle and Kirkpatrick 2001). It has been documented that with increased grazing intensity the persistence of many grassland species decreases (Moore 1970, Stuwe and Parsons 1977, Hamilton 2001). Grazing at low intensity with optimal resting periods for flowering and seed set may maintain or even enhance species richness (Lunt 1997). Spring and summer rest from grazing is thought to maintain species richness (Diez and Foreman 1997, Milne *et al.* 1999), allowing species that sexually reproduce in these seasons to flower, set and release seed.

The susceptibility of palatable perennial species to grazing may vary temporally and depend on their relative investment in longevity and seedling recruitment as strategies to persist in vegetation community. For example plant species with under-ground storage organs may be most susceptible to grazing late in the growing season when grazing may limit the ability of the plant to replenish root reserves. In contrast, short-lived perennials that invest more heavily in seedling recruitment may be most impacted by grazing early in the growing season, particularly if it reduces flower and seed production. If plant life-history strategies, grazing effects and variation in temporal responses are understood, management can be modified to favour persistence of palatable species. By using the grazing analogue treatment of clipping and trampling, the responses of the nationally endangered native legume, *Cullen parvum*, to selective and non-selective grazing was investigated.

Methods

Species Description

Cullen parvum (Fabaceae) is listed as endangered both nationally (Briggs and Leigh 1988) and in Victoria (DNRE 2000). This species is listed as a threatened taxon on Schedule 2 of *the Flora and Fauna Guarantee Act* 1988. *Cullen parvum* is a trailing or ascending perennial herb, almost hairless with short slender stems and trifoliate leaves. Flowering occurs from October to March, usually peaking in December to February. If there is sufficient rainfall another flush of flowering and seed production may be initiated, however, if rainfall occurs late in the season, seed may be unable to fully mature (DNRE 1998). It is a seasonal hemi-cryptophyte, re-sprouting in spring from a thick, woody rootstock that may be >50cm long. *Cullen parvum* occurs in the Western (Basalt) Plains Grassland community, which is itself threatened and listed under the *Flora and Fauna Guarantee Act* 1988. It is likely that grazing by livestock has led to declines in the abundance and distribution of this species. Legumes are valued in grazing ecosystems because of the role they play in nitrogen fixation (Smith 2000).

Site selection

Two grazed grasslands supporting large populations (> 1,000 individuals) of *Cullen parvum* were selected on the Western (Basalt) Plains, near Shelford in Victoria (Figure 1). Each site was within a paddock used for commercial sheep production. Although both sites were within the same property they were separated by approximately one kilometre and occurred in separate paddocks, Corner (Site 1) and Gully (Site 2) paddocks. The Western (Basalt) Plains Grassland Community (FFG 1988) is dominated by the tussock grasses *Themeda triandra* with *Austrostipa* and *Austrodanthonia* species as sub-dominants. Perennial herbs (native and exotic) occupy inter-tussock spaces and eleven threatened plant species have been recorded as part of the community. The community occurs on flat to undulating basalt soils and is characterised by low rainfall, with maximum precipitation occurring from May to October (Figure 2).

Figure 1. Distribution of the Western Basalt Plans in Victoria (shaded areas), showing the location of the Study area near the town of Shelford.

Experimental design

Both of the experimental sites were enclosed in a permanently fenced plot (12m x 12m), which was established in October 2002. Three replicates of each of the following grazing analogue (clipping and trampling) treatments were established in a randomised block design at each site.

Selectivity of ‘grazing’ treatments:

(1) Control, ungrazed (C)

(2) Selective, ‘grazing’ of *Cullen parvum* only (S)

(3) Aversion, ‘grazing’ of all vegetation, excluding *C. parvum* (A)

(4) Non-selective, ‘grazing’ of all vegetation, including *C. parvum* (N)

Timing of ‘grazing’ treatments:

(1) Early - early summer (E): one clipping in November (2002 & 2003).

(2) Late - late summer (L): one clipping in February (2003 & 2004).

(3) All year (A): three clippings per season, November (2002 & 2003), January and February (2003 & 2004).

There were 12 treatments in total (‘grazing’ x timing) with three replicates per treatment at each site. Thirty-six random 25 x 25cm quadrats were established in each of the sites. Each of these quadrats was further divided into 5cm x 5cm grids. These grids were used to accurately record the location of each *C. parvum* individual. There was a 25cm buffer zone surrounding each quadrat.

In the ‘grazing’ treatments, plants were hand clipped (using shears) to approximately 0.5cm above the soil surface. Quadrats with clipped vegetation were heavily trampled by the same person for 20 seconds to simulate soil compaction from sheep. Clipping treatments were ceased in February and sampling in summer 2004/2005 was used to examine residual effects of these treatments.

At each sampling period plant survival, size and reproduction were assessed for *C. parvum*. Plant size was estimated by measuring the length of the longest stem, from soil surface to the tip of the last leaf on the stem and by counting the number of main stems per plant. The number of buds, flowers and fruits per adult plant were counted to assess reproductive effort. The total number of buds, flowers and fruits per plant provided an estimation of total reproductive investment at that point in time.

Palatability

The palatability of *C. parvum* and commonly occurring pasture species were measured as follows. Approximately 250 grams wet weight of whole *C. parvum* plants and at least two random pasture samples, excluding the root system, was collected in November, December, January and February of 2003/2004. These were dried at 48^{o}C for 48 hours and approximately 10 grams were sent to the *Feedtest*® laboratories at the Department of Primary Industires, Hamilton. Samples were analysed for digestibility, digestible dry matter, crude protein, metabolisable energy and neutral detergent fibre. The following descriptions are adapted from *Feedtest*®. (1) Digestibility is the solubility of the structural components, the degree of lignification and the portion of the plant that is digested (Leigh and Noble 1972).

Digestible dry matter (DDM) is the percentage of dry matter probably digested by animals, where feeds of high quality have a score greater than 65% and low quality below 55%. (2) Crude Protein is the amount of protein (amino acids) and non-protein nitrogen in a sample. (3) Metabolisable energy is the probable amount of energy derived from the sample that the herbivore uses. Expressed as megajoules/kilogram of dry matter. (4) Neutral detergent fibre is an estimate of the total cell wall content and indicates the fibre content available.

A detailed literature search was also undertaken to assess presence of secondary metabolites and other evidence of palatability in *C. parvum* and related plant species.

Below ground growth
Ten plants of varying size were excavated in December 2004. The number of main branches and root dimensions were recorded.

Data analysis

Plant Index
An index of plant performance per quadrat (*PI*) was calculated as the natural logarithm of the total number stems per quadrat, multiplied by the average longest branch length across all ramets* present in the quadrat. The probability of reproductive effort (presence of inflorescences), proportion of ramets with inflorescences and the total reproductive effort were also modelled at a whole quadrat scale.

Data analyses were conducted using either Analysis of Variance, Linear Mixed Models using Restricted Maximum Likelihood or Generalised Linear Mixed Models. In all cases full models were initially fitted and following examination of diagnostic plots and appropriate transformations, terms with either a variance ratio or χ^2 probability >0.1 were deleted from models.

Changes in *PI* over the first two years of the experiment was modelled using a linear mixed model with restricted maximum likelihood (REML) (Corbeil and Searle 1976). The random model was quadrat nested within site and the fixed model incorporated interactions between year, selectivity and frequency and a simple model of plant growth over the growing season. In this case growth was assumed to fit a theoretical growth curve approximated by a third order polynomial ie. $\text{month}^3 + \text{month}^2 + \text{month}$, where month was a continuous variable with values of 1 (October) to 5 (February).

A separate analysis, using ANOVA, was undertaken to examine whether treatments had an effect on *PI* in the season following the completion of the experiment (December 2005). The treatment structure was the interaction between frequency and selectivity and the block structure was site.

Reproduction
The probability of reproduction per quadrat for 2002/2003 and 2003/2004 was modelled using generalised linear mixed models (GLMM), a generalised linear model with both fixed and random effects, in Genstat 7.2. Models were constructed with a binomial error distribution. The random model was quadrat nested within site and the fixed model was the interaction between year, frequency, selectivity and month.

The total reproductive investment per quadrat (summed number of immature and mature inflorescences) was modelled using a linear mixed model with REML in Genstat following natural log transformation (+1) of the response variable.

*A ramet is an individual member of a clone, as an offshoot of a plant reproducing by stolons. A stolon is a creeping plant stem or runner capable of developing rootlets and stem and ultimately forming a new individual (Lawrence 1997).

Results

Palatability

Averaged across the growing season crude protein, metabolisable energy and digestibility tend to be higher while neutral detergent fibre tends to be lower in *C. parvum* than in adjacent pasture samples lacking this species. These results suggest that relative to adjacent pasture, *C. parvum* could on average provide higher forage quality.

Table 1. Forage quality, indicated by crude protein, metabolisable energy, digestibility and neutral detergent fibre for six random *Cullen parvum* samples and eight adjacent random pasture samples collected in grazed native grassland near Shelford, Victoria. Mean and 95% and 5% quartiles are presented.

	Cullen parvum (n=6)			**Pasture (n=8)**		
	Mean	**95%**	**5%**	**Mean**	**95%**	**5%**
Crude Protein (%)	17.3	22.6	12.4	8.0	13.6	3.7
Metabolisable Energy (MJ/kg)	9.4	10.6	8.4	7.4	9.1	6.1
Digestibility (%)	65.3	72.6	58.8	53.0	63.5	44.6
Neutral detergent Fibre (%)	41.3	47.1	36.3	67.0	77.8	57.2

Our literature research found no information specific to *C. parvum* although research has been undertaken on other species in this and related genera in Australia and overseas (*Psoralea* syn *Cullen*).

Psoralea (*Cullen*) *eriantha* observed to be palatable to cattle and persistence declined under grazing (Kerridge & Skerman 1968). While *P. tenax* was observed to be utilised by livestock it persisted under a range of grazing regimes in *Astrebla* grasslands (Orr 1980). No toxic effects on livestock have apparently been reported (Cunningham *et al.* 1981).

While there is published and anecdotal evidence of both the forage quality and palatability of *Cullen* species in Australia, the metabolite furanocoumarin is considered to be a chemotaxonomic marker in the genus (Professor Bourgaud, pers. comm.). Furanocoumarin content apparently increases with plant age, is highest in fruits and increases with imposition of stress (Bourgaud *et al.* 1992). Thus it is possible that grazing may induce production of these compounds. These molecules have been known to result in liver and photo toxicity in humans, although nothing is known for livestock. Indeed it is possible that furanocoumarins may be partially or totally degraded by rumen microflora (Bourgaud, pers. comm.), which may explain the absence of reported toxic effects in Australia.

Plant Growth

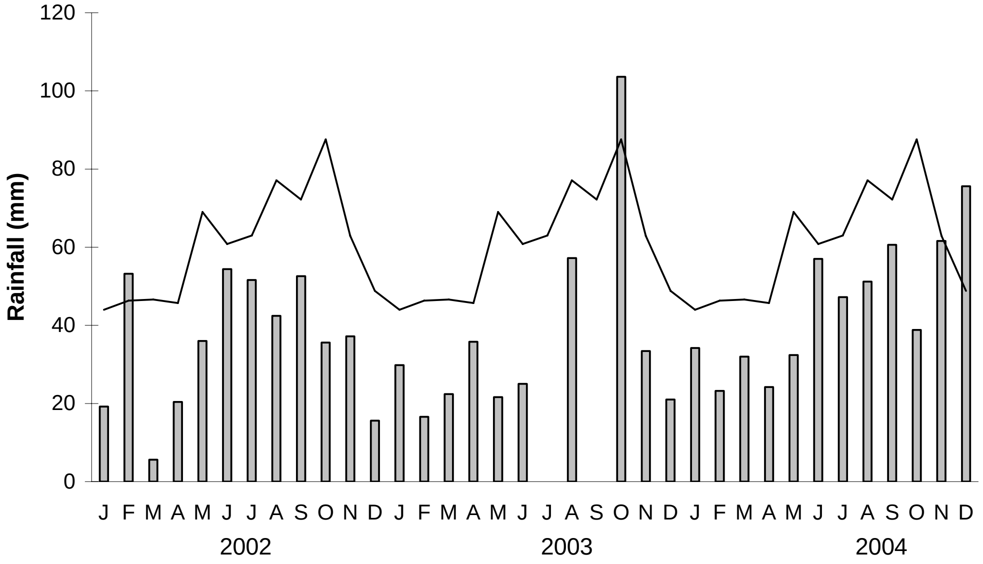

Figure 2. Monthly rainfall (bars) for 2002 to 2004 and mean monthly rainfall (solid line) from 1972 to 1983 at Shelford, Victoria. Arrows indicate the initiation of the experiment, completion of experimental treatments and final sampling.

Plant growth differed between the first two years of the experiment (Year, df=1, wald=32.28, χ^2 <0.001) (Figure 3). In the first year, plants performance rapidly declined between January and February, which coincided with below average rainfall (Figure 2). In the second year plant performance only showed a rapid decline in those quadrats where *C. parvum* was grazed (Selectivity x Year, df = 3, wald=32.33, χ^2 <0.001; Selectivity x Month, df = 3, wald = 60.73, χ^2 <0.001) (Figure 3).

In both January and February of year two the plant index was greatest in quadrats where *C. parvum* was ungrazed. In year one the plant index values for ungrazed *C. parvum* treatments apparently only differed in February and were smaller than those in year two.

In both years no difference in the performance index was observed between selective and non-selective grazing treatments. Furthermore, aversion grazing resulted in no positive benefit for the plant size index of *C. parvum*, and although not significantly different there was a trend for slightly poorer performance in aversion quadrats compared to controls.

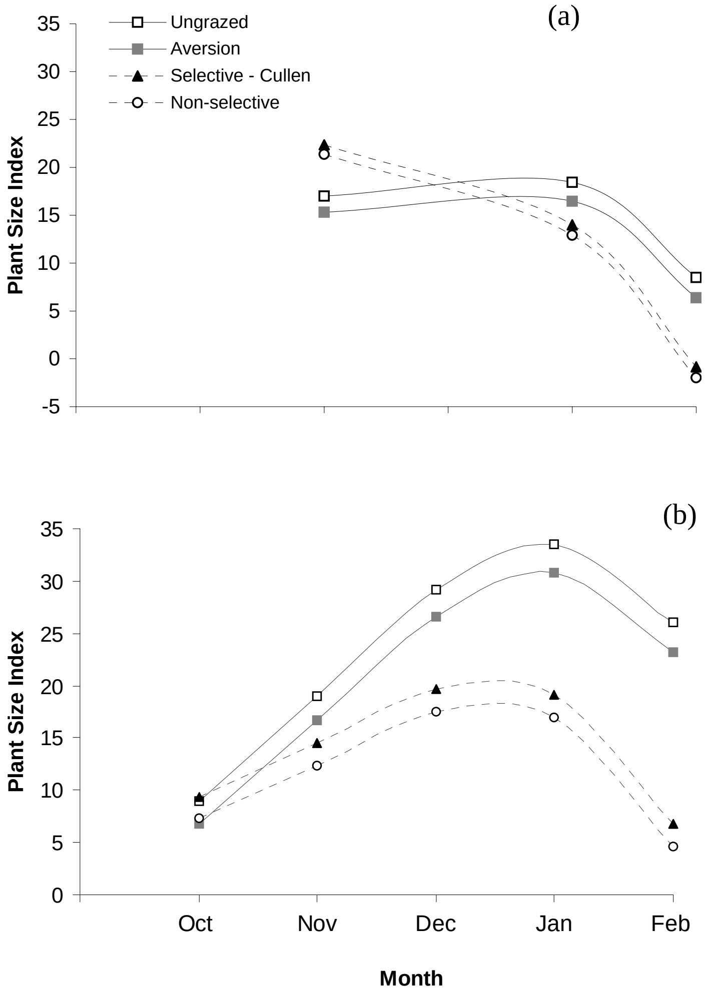

Figure 3. Predicted average plant size index across four grazing selection treatments in (a) 2002/2003 and (b) 2003/2004.

In year three no effect of grazing frequency was observed ($F_{2,58}$ = 0.64), although weak differences in the plant index were observed between grazing selection treatments (ANOVA, Selectivity, $F_{3,58}$ = 2.7, p = 0.056) (Figure 4).

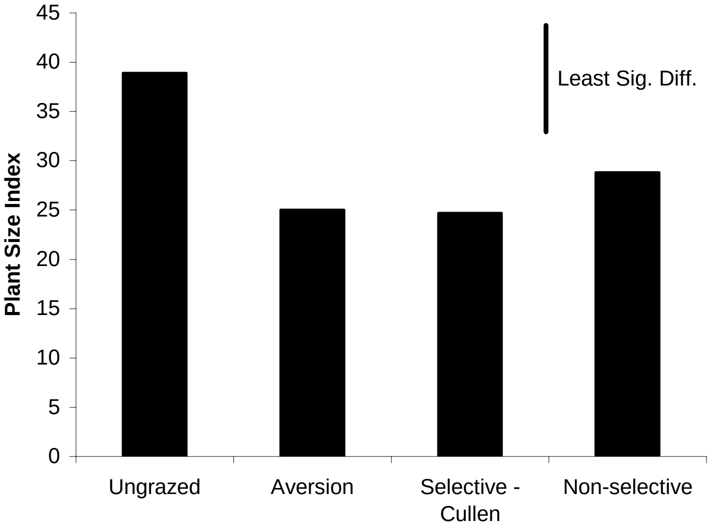

Figure 4. Predicted average plant size index model across four grazing selection treatments in December 2004, derived from an ANOVA model. Bar is least significant difference at 5%.

Reproduction

Total reproduction output per quadrat (summed number of inflorescences across all ramets) peaked in January and declined to almost zero by February in both years one and two (Month, df = 4, wald = 315.7, χ^2 <0.001). There was a weak interaction between grazing selectivity and year (Selectivity x Year, df = 3, wald=7.34, χ^2 = 0.062) due to lower inflorescence and fruit production in year two in quadrats where *C. parvum* was selectively grazed. Overall inflorescence production was lower in year two (Year, df = 1, wald=11.5, χ^2 < 0.001).

Differences in reproduction between selection treatments were most marked in year two, with much lower probabilities in those quadrats where *C. parvum* had been selectively grazed (Figure 5a). In year one there was a weak trend to suggest that the highest probability of producing inflorescences occurred in ungrazed quadrats, while slightly lower probabilities were predicted in non-selectively grazed quadrats (Figure 5a). In year one, grazing early in the growing season increased the probability of reproduction relative to those grazed in late summer while in year two there was little difference between treatments (Figure 5b).

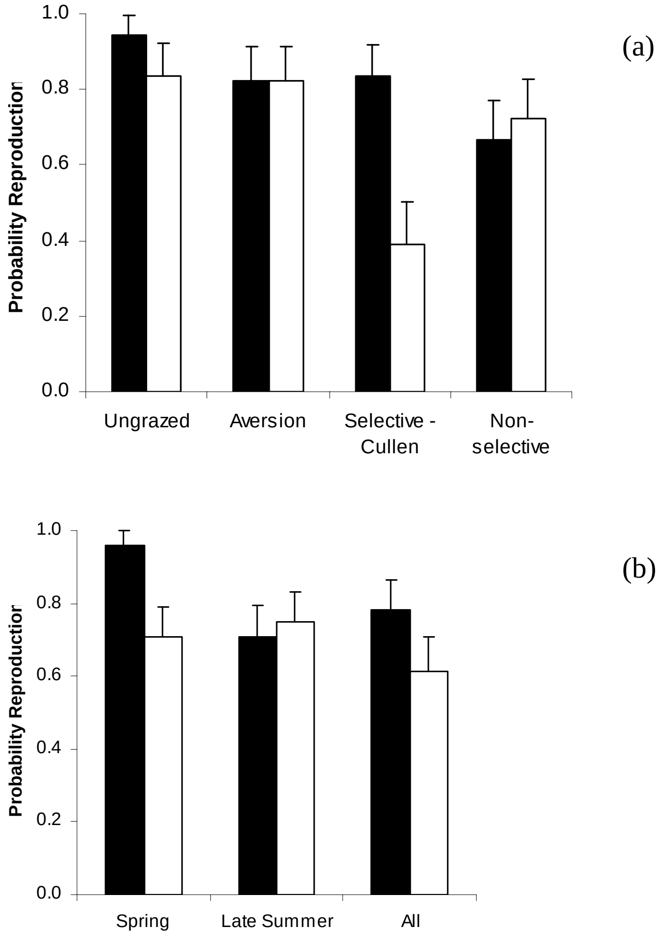

Figure 5. Predicted probability of inflorescence production per $0.125m^2$ quadrat in January of 2003 (filled) and 2004 (open) in response to (a) grazing selectivity and (b) grazing frequency. Bars are 2 standard errors.

Excavation of ten *C. parvum* plants at Shelford indicated that central ‘nodes’ or ramets from which above ground stems arise which can derive from below ground branches extending between 1cm to 8cm from a central taproot (Figure 6). Each plant can produce several ramets (mean=2.8 ± 2.1, n = 10). Plants developed deep taproots and several extended well beyond 50 cm depth (mean = 41.1 ± 17.3, n = 10). The number of branches tended to increase with root depth.

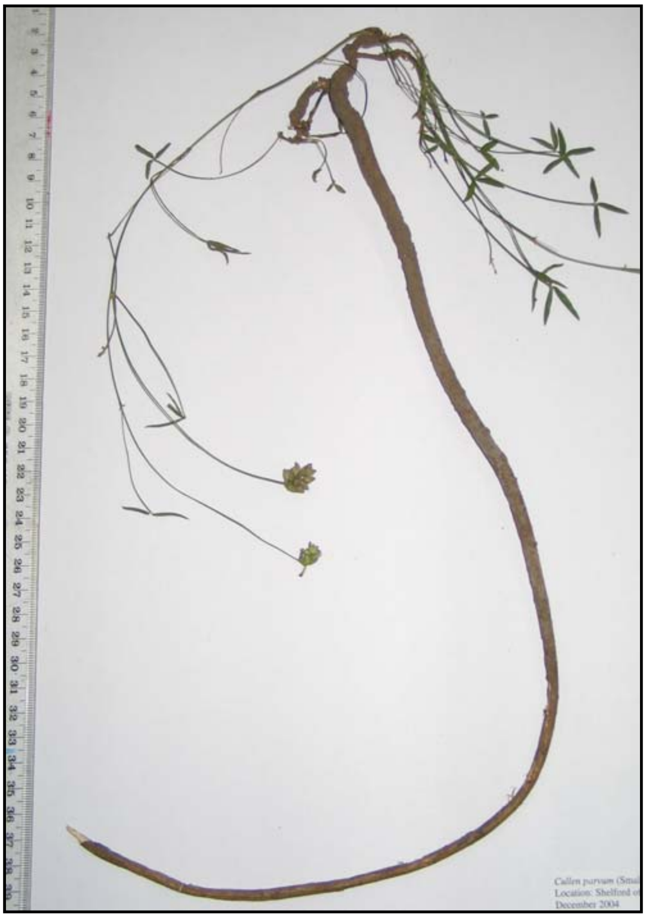

Figure 6. Photographs of *C. parvum* plants excavated at the field sites displaying central 'nodes' or ramets which arise from below ground branches. The main taproot can extend to a depth > 50cm. Photograph (a) two young plants, (b) an older plant and (c) displays above ground 'ramets' and below ground branches. nodes.

Conclusion

Both selective and non-selective grazing reduced the growth and reproduction of C. parvum. Furthermore treatments in which all other plants but *C. parvum* were grazed had similar, albeit slightly lower, growth responses to ungrazed plants. In the year following cessation of the experiment plants in all grazed treatments, even where *C. parvum* was avoided, were smaller than in ungrazed treatments. Grazing frequency had little influence on plant size.

Under set-stock grazing systems, grazing animals are able to selectively forage, leading to alterations in the competitive hierarchy between plant species and particularly to a decline and eventual loss of palatable species. Shifting to grazing regimes that reduce animal preference, such as short duration high density grazing management is argued to reduce animal selection of preferred species, enhancing persistence of palatable species in grazed grasslands. Alternatively the persistence of plant species in rotational systems may simply arise due to increased lengths and frequency of rest between grazing events. The results of this experiment suggest that direct grazing impacts, not changes in competitive hierarchies are important for *C. parvum*. As a result targeted grazing strategies such as removal of grazing animals through the growing season (particularly late in the growing season), will most likely favour growth, abundance and flowering of this plant species. While complete absence of grazing is most beneficial, results suggest that grazing once early in the growing season (eg. resting from late spring to late summer) favours the persistence and flowering of *C. parvum* relative to late summer and multiple grazing events through the growing season.

While further field studies using livestock are required to confirm the results presented here we recommend that in sites managed for the persistence of this species, livestock access should be minimised through the growing season, particularly in summer months.

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