Chapter 6 Effect of grazing management and class of stock on Chilean needle grass (*Nassella neesiana*) seed production

6.1 Abstract

Concern about the invasion of pastures in southeastern Australia by Chilean needle grass (CNG, *Nassella neesiana* (Trin. & Rupr.) Barkworth) began to mount in the 1970s. CNG infestations can reduce stock carrying capacity during late spring and summer. This is because of the production of large numbers of unpalatable flower stalks. These flower stalks are actively avoided by stock, and have sharp seeds which can penetrate the hides of sheep. Research into CNG management in Australia has shifted towards using grazing as a tool to both manage and utilise CNG. This chapter describes an experiment that commenced in spring 2004, comparing methods of set stocking and rotational grazing in full paddock systems using both sheep and cattle as grazing species. All grazing treatments were stocked at 12DSE/ha with rotational treatments made up of a 4 paddock grazing system.

Grazing (by sheep or cattle) reduced the occurrence of standing CNG panicle and stem cleistogene seed during 2004 and 2005 when compared with ungrazed plots however in 2005 the result was not significant due to high variability in the data. Grazing did not significantly affect the viability of harvested panicle seed in 2004 or 2005.

Cattle tended to graze more standing CNG panicle seed than sheep during the 2004 season. This did not re-occur during the 2005 season as cattle were not rotationally grazed. Panicle seed viability and cleistogene production were not significantly affected by the type of grazer during 2004 or 2005. Cattle tended to graze plots less selectively than sheep. Liveweight gains of both sheep and cattle were not significantly different.

Grazing had a limited effect on pasture composition over the experimental period. Basal cover of the pasture species was unaffected by grazing. The regrowth of pasture in grazed plots had significantly less CNG in 2004 than ungrazed plots and regrowth in cattle plots had significantly more desirable perennial grasses than sheep plots during October 2005. Both sheep and cattle gained weight acceptably.

Grazing method, using set stock or a 4 paddock rotational grazing system, did not significantly affect the number of panicle seeds, panicle seed viability or number of stem cleistogenes harvested in 2004 and 2005. Pasture yield and the composition of the pasture regrowth was not affected by grazing method (set stock vs rotational).

The use of cattle to graze CNG infestations tended to be better than the use of sheep. Cattle tended to graze more CNG panicle seeds than sheep and have a lower risk of seeds penetrating their skin or being spread by their hair.

6.2 Introduction

Chilean needle grass (CNG, *Nassella neesiana* (Trin. & Rupr.) Barkworth) is a highly invasive perennial spear grass (Gardener 1996; Storrie and Gardener 1998). Concern about the invasion of pastures in southeastern Australia by CNG began to mount in the 1970s. CNG has also been recognised as potentially the worst environmental weed of grasslands in southeastern Australia (McLaren *et al.* 1998). Current research into CNG management in Australia has shifted towards using grazing as a tool to both manage and utilise CNG.

In Argentina, its country of origin, CNG is valued for its winter stock feed whilst the plant is still in its vegetative state (Rosengurtt *et al.* 1970). However, during warmer months the production of large amounts of unpalatable flower stalks and very little leaf causes a severe reduction in plant production and reduces stock carrying capacity by up to 75% (Duncan 1993; Gardener 1996; 1998; Storrie and Gardener 1998). These flower stalks are actively avoided by stock, and the sharp seeds can penetrate the hides of sheep. Seed yields of up to 30,000 seeds/m^2 have been recorded (Slay 2001).

Most propagules of CNG will not naturally move far from the parent, although the panicle seeds will readily attach to many moving objects since they have a callus with backwards facing hairs at the point of the seed (Gardener *et al.* 2003a). The majority of CNG seeds are spread by livestock, machinery, and infested hay.

6.2.1 Chilean needle grass spread by sheep

Wool is an effective means of CNG seed dispersal. Panicle seeds will readily attach to wool on the head and belly of sheep and remain attached for extended periods (Gardener 1998). Five months after seed attachment, a sheep may still be carrying up to 25% of its original seed load. However most of these seeds will lack awns, thus they will be less able to become buried in the soil and germinate (Gardener 1998). Gardener (1998) found that shearing at seed set of CNG significantly reduced the occurrence of seeds lodging in the fleeces of sheep. This strategy however, is risky as the fleece may regrow during the prolonged flowering period of CNG and seeds may still attach and be spread.

6.2.2 Chilean needle grass spread by cattle

The panicle seeds of CNG are reported to be unable to penetrate the hides of cattle and are therefore less likely to be spread by this means (Gardener 1998) yet some producers have had cattle with abscesses and infections caused by CNG seeds (Kissel 2004; McKenzie 2003). When mixed with other feed supplements, a small percentage of the seeds of CNG can pass through the gut of cattle without causing any damage. Gardener (1998) found that 0.51% and 2.7% of panicle and cleistogamous seeds respectively passed through the gut of cattle in a viable state. Gardener (1998) found that the greatest seed output in the manure was 24-48 hrs post feeding.

6.2.3 *Animal hygiene to reduce seed spread*

All management strategies should incorporate techniques to restrict the spread of CNG seed. Any access yards and roads should be kept weed free to limit uptake of weed seed (Taylor and Sindel 2000). Any machinery or personnel used to move livestock between infested and clean paddocks should also be inspected and cleaned prior to moving into clean areas (Bourdot 1988; Gardener *et al.* 2003a).

Livestock on farms that have any CNG infestations should not have access to areas where CNG is in seed head (Hawke's Bay Regional Council 2002). If livestock movement is 'off farm,' from infested properties, stock should be deseeded or sold direct to slaughter (Bourdot 1988).

If animals have been near CNG infestations or are contaminated, including mud in hooves, they should only be put onto clean pastures once they have been cleaned. A seven day with-holding period for cattle will ensure gut contents and hooves are CNG seed free (Bourdot 1988). A withholding period for infested sheep is useless as seeds are likely to become embedded in fleeces (Gardener *et al.* 2003a). Cleaning may also be by means of shearing or clipping prior to moving stock into clean pastures.

To reduce the likelihood of viable seed attaching to animals and machinery, non selective herbicides can be used at spraytopping rates to stop seed head development thus protecting sheep welfare (Slay 2002b).

6.2.4 *Grazing characteristics of different livestock species*

Livestock species differ in the degree to which they affect the pasture in terms of selective grazing or their physical characteristics (i.e. horses and cattle have large hooves capable of creating gaps in pasture)(Popay and Field 1996). Selective grazing can be due to the type of animal but it can also be influenced by the grazing pressure and stocking rate (Friend and Kemp 2000; Popay and Field 1996).

Sheep have been known to eat many weeds that are normally avoided by cattle (Friend and Kemp 2000). At high herbage mass, sheep are known to select for green leaf and clover whilst also grazing closer to the ground than cattle (NSW-Agriculture 1998).

In a paddock with high herbage mass, cattle are less selective for green feed than sheep and will tend to remove tall grasses (Friend and Kemp 2000). Cattle can graze selectively according to the attractiveness of the plant – thus causing a pasture population shift over time if the pasture is continuously grazed exclusively by cattle (NSW-Agriculture 1998). Campbell (1995a) found that cattle will leave more leaf area of pasture than sheep, thus providing better competition for weeds (e.g. serrated tussock (*Nassella trichotoma*)) in pasture.

Goats may provide the ability to graze seed heads left over by other stock as they graze evenly from the top of the sward downwards (Friend and Kemp 2000; Popay and Field 1996). Goats are also said to prefer grasses to clover/legumes, allowing clover to dominate and compete with weeds such as serrated tussock (Campbell 1995a). Goats have the ability to control weeds as they can prevent flower development, preferentially graze weedy species (putting them at a competitive disadvantage), or mechanically damage them (i.e. through ringbarking)(Holst 1980). Thus goats can save farmers money on chemical weed control, be more environmentally acceptable, and provide a financial return (Allan *et al.* 1993; McGregor 2003b). Goats have been reported to be more selective than sheep and have adapted to prickly and bitter tasting plants as well as nibbling on young shoots – since they have a narrower muzzle than sheep (McGregor 1985; 1990; 1995; McGregor and Presidente 1985). Meat goats and/or low grade fibre goats are suitable for weed control (Allan *et al.* 1993). This experiment did not compare grazing with goats to sheep or cattle, as poor seasonal conditions meant that a suitable farm was not found within the time constraints.

6.2.5 Grazing management for Chilean needle grass infestations

Stock policy

If grazing is restricted to one class of stock (e.g. sheep only or cattle only), whether it is a managed grazing situation or not, the likelihood of a problem occurring with a particular weed is increased (Popay and Field 1996). It is recommended that different classes of stock be introduced into paddocks to 'clean up' ungrazed plants/weeds left over in the pasture (Popay and Field 1996). Complementary goat grazing, at low or recommended sheep stock rates, is said to provide gains in both sheep wool and meat production whilst reducing the occurrence of internal parasitism (McGregor 1985; 1990; 2002; McGregor and Presidente 1985).

Grazing method and Chilean needle grass

Strategic stocking can be used to manage pasture areas infested with CNG (Duncan 1993). Stock will eat CNG, even as it becomes unpalatable, if other feeds become scarce (Duncan 1993). In Argentina, cattle producers advocate a rotation of 50-100 days with 5-10 days on, until the CNG starts to dry off. Once the CNG has dried off, the cattle are sold from the infested farms. The remaining dry CNG plants are burnt prior to the next grazing season (Gardener *et al.* 1996b). This strategy is also incorporated into sheep production systems of south central Victoria where CNG infested paddocks are not grazed over the flowering period (Oaklands Junction; (Alston and Alston 2003)). In terms of the CNG soil seedbank, it was found that heavy grazing with cattle had little overall effect on the soil seedbank of CNG, when compared with ungrazed plots (Lowien 2002; Lowien *et al.* 2001).

Grazing method and pasture composition

Grazing method is the timing of grazing, combined with strategic rest periods, to manipulate the pasture composition based on the comparative phenology and ecology of the less desirable plant (Dowling *et al.* 2000; Friend and Kemp 2000). The method of grazing aims to exploit differential effects of grazing on the target weed compared with the desirable species. Grazing pressure should be applied when the weed is most susceptible to damage from grazing, and conversely when the desirable species are not so vulnerable (Friend and Kemp 2000). Grazing at the reproductive phase will have greater effect on seed production by removal of floral parts, while grazing at the vegetative phase may delay flowering. Tolerance to grazing will also be reduced if the plant's carbohydrate reserves are low (e.g. new growth removed or weakened by drought) because plant growth relies on the production of carbohydrates by green foliage through photosynthesis. Any loss of foliage has the potential to reduce reproductive plant growth and the plants' reproductive potential. These periods of sensitivity to grazing often apply equally to desirable plants and weeds (Friend and Kemp 2000). The botanical composition of a pasture can be influenced by:

1. when the grazing occurs;
2. the grazing pressure;
3. the method of grazing; and
4. the type of livestock.

In terms of animal preference, desirable plants are generally disadvantaged during grazing as they are selected over undesirables (Friend and Kemp 2000). Selective defoliation of palatable species allows unpalatable species to realise a competitive advantage (Moretto and Distel 1999). Moretto and Distel (1999) also found that in the presence of defoliated palatable plants, unpalatable plants had a larger basal area, end of season aerial biomass, seed production, total green blade length per tiller and tiller dry mass. They suggested that selectivity can be reduced by high intensity low frequency grazing events. This suggestion is assuming that the palatable species are at least as tolerant to grazing as are the unpalatable species.

Stock rate

Stock rate is the dominant management factor in determining the efficiency of pasture utilisation by sheep and cattle. Grazing method is less important than the stock rate although significant interactions between stock rate and grazing method exist (McMeekan and Walshe 1963).

If the stock rate is too high, pasture production will be reduced and there is the risk of destroying the pasture community causing less palatable species to become dominant (McGregor 2002). Apart from the stress imposed on the stock, there are also issues concerning soil conservation. Stock rate can be measured by the animals' Dry Sheep Equivalent (DSE). The DSE is the estimated energy requirement to maintain body weight of a two year old merino wether (non breeding) weighing 45 kg (McGregor 2002). An animal's DSE requirement depends upon its average body weight, rate of growth, pregnancy status, level of physical activity and environmental cold stress.

6.2.6 Experimental aim

The aim in this trial was to compare the ability of sheep and cattle to reduce the production of CNG in set stock or 4 paddock rotational grazing systems whilst monitoring the effects of grazing on pasture composition and rate of growth.

6.3 Materials and Methods

6.3.1 Location

The experiment was conducted at 'The Elms' in Greenvale, Victoria Australia (38°04' S, 141°40' E). The paddocks generally had an even cover of CNG and had been grazed by sheep in the past with a more recent history of cattle grazing in the past five years. The farm is on grey brown fine to very fine sandy loam soils with an Olsen P of 9 – 17 mg/kg and average pH of 5.28 (1:5 water). Rainfall over the spring to early summer period (September to December) of 2004 and 2005 was 265.5 mm and 221 mm respectively (measured at Melbourne airport – 5km from trial site)(Table 6.1).

Table 6.1 Monthly and annual rainfall at Melbourne Airport (mm).

Month	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
2004	24.4	9.8	20.2	49	18.2	24.2	27.8	69.4	47.8	45.2	113	59.2	508.2
2005	24	200.6	7.8	26	8	31	21.8	57.6	39.4	69	64.6	48	597.8

6.3.2 Design and treatments

The trial consisted of five fully randomised treatments replicated twice along the sides of a valley. Treatments included sheep and cattle grazing under both set stock or rotational grazing systems over the spring period of 2004 and 2005 as well as ungrazed control plots (Table 6.2,Figure 6.1, Figure 6.2). Plots were grazed intermittently for the remainder of the year due to negligible pasture. Each treatment was stocked equivalent to 12 DSE/ha (over the spring period only) made up of cows and calves (4.5 – 10 ha plot size) or sheep with lambs at foot (0.5 ha plot size). Rotational grazing treatments consisted of 4 paddocks in which livestock were allowed to graze in one paddock only, and then moved through to the next available paddocks in a 'rotational' manner. The length of grazing rotation started at 8 weeks (2 weeks in, 6 weeks out) during early spring and was shortened to a 4 week cycle (1 week in, 3 weeks out) by late spring and early summer as the rate of grass growth increased. Thus paddocks in the rotational grazing treatment had a peak stock rate of 48 DSE/ha for ¼ of the time, equalling 12 DSE/ha overall. Both the boundary and internal fences (grazing cells) for the cattle treatments were electric wires, whilst sheep proof mesh (Ringlock 7/90/30) was used for all fences of the sheep treatments (Figure 6.2). All paddocks had water troughs fed by a header tank.

Table 6.2 Stock class grazing trial treatments.

Treatment number	Grazing regime	Grazing stock
1	No grazing	-
2	Set stock	Cattle
3	Rotational[A]	Cattle
4	Set stock	Sheep
5	Rotational	Sheep

[A] Due to unseasonally dry conditions in 2005, changes to property management meant that a rotational cattle system could not be implemented for the 2005 season. Cattle were only set stocked for the 2005 experimental period

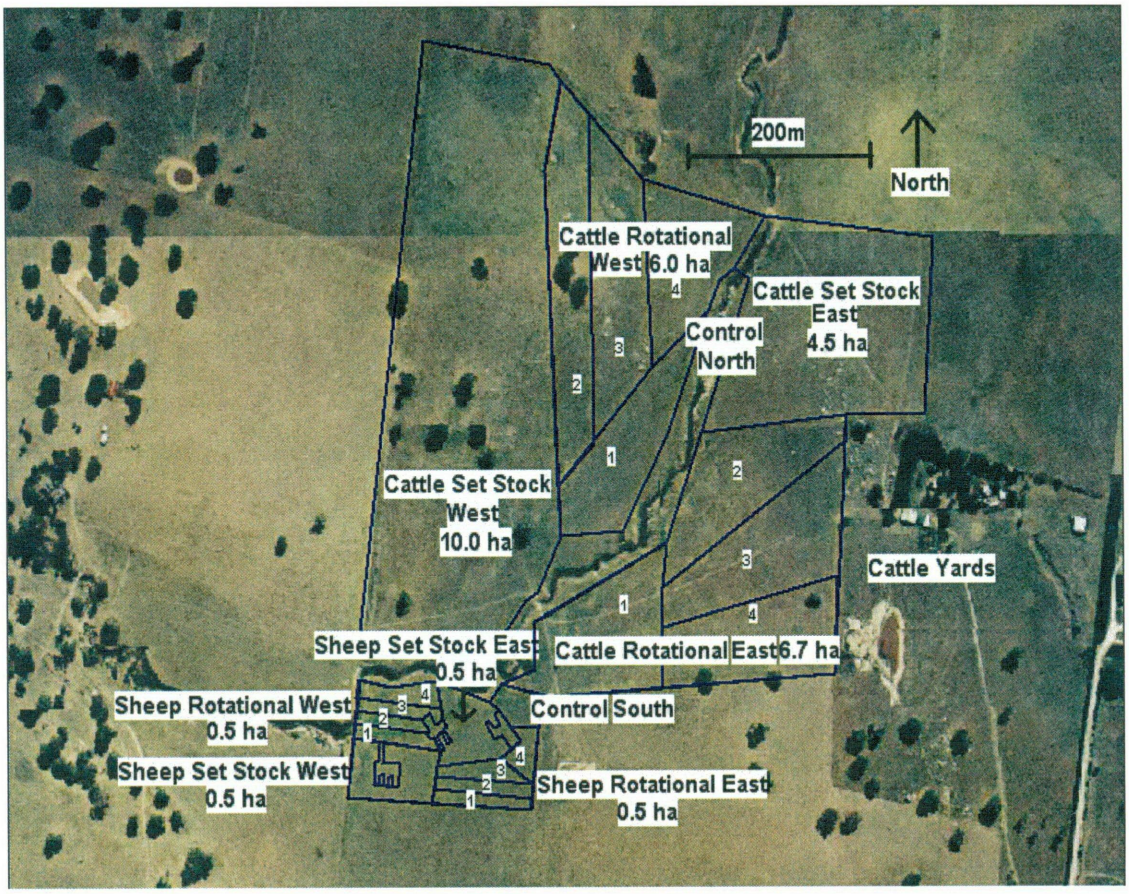

Figure 6.1 Stock class grazing trial plot layout and effective grazing area for each treatment (including rotational grazing paddock numbers).

Figure 6.2 Electric fencing and ringlock fencing used for stock class experiment.

6.3.3 Setup and sampling

Prior to each spring grazing period, all stock were weighed, young stock paired to their mothers, stratified by liveweight of the mothers and then randomly allocated to their treatments. Animals were allocated into grazing groups by 30th August 2004, and 8th September 2005. Liveweight was recorded monthly for both sheep and cattle (2004 only, due to changes to farm management) using walk over scales (Figure 6.3). Young stock were included in weighing after birth. Sheep condition score was also recorded for sheep (Standing Committee on Agriculture 1990).

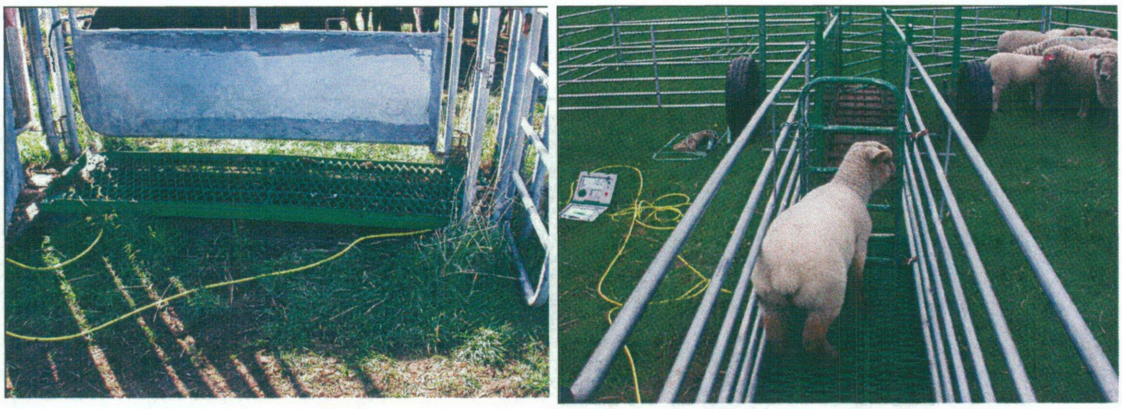

Figure 6.3 Walk over scales used in cattle crush and portable sheep yards.

All pasture and seedbank measurements were collected on two transects that spanned each treatment paddock. Pasture measurements included basal pasture composition, available pasture mass, species growth rates and number of ungrazed standing CNG stems (Panicle and stem seed measurements).

Pasture composition was recorded on the 20th September 2004 and 21st October 2005. This was done using a 100 point 1x1m quadrat recording basal plant observations at 8 positions per paddock. The basal measurements were categorised as either CNG, perennial desirable grasses (*Phalaris aquatica* and *Dactylis glomerata*), broadleaf weeds (e.g. *Arctotheca calendula*), other annual species (e.g *Hordeum leporinum, Romulea rosea*), legumes, vegetative litter or bare soil.

Available pasture mass and pasture growth (kgDM/ha) was measured using a rising plate meter calibrated monthly at the trial site by drying pasture cuts to constant mass in an oven. Available pasture mass was measured across all paddocks at the time when rotational grazing stock were shifted into a new grazing cell.

Pasture growth was measured inside four circular steel mesh pasture cages per transect (80 cm diameter 40 cm high; Figure 6.4). The pasture cages were used in all set stock treatments as well as the active cell of rotational grazing treatments to exclude grazing. Pasture growth measurements were taken inside the cage whilst available pasture was measured outside of the cage.

Figure 6.4 Pasture cages used for measuring ungrazed pasture mass.

Species growth rates (as dry matter yields) were calculated using BOTANAL, a dry weight ranking method (using 25 x 25 cm quadrats positioned 8 times along the measurement transect) (Haydock and Shaw 1975; Mannetje and Haydock 1963). Measurements for spring 2004 were taken on 14th September, 22nd October and 14th December. Measurements for spring 2005 were taken on 18th October and 12th December. Measurements taken in October aligned with the completion of the first rotation. Measurements taken after this time were from under pasture cages and were protected from grazing.

Reproductive stems of all pasture species were harvested at ground level from six 30 x 33 cm quadrats per plot positioned along the measurement transect prior to seedfall on 2nd December 2004, and 5th December 2005 using hand shears. Stems were dried, sorted and

CNG panicle seeds and stem cleistogenes removed and weighed. The number of panicle seed per treatment was calculated by weight of complete seed ($y = 115.41x + 2.5645$ $R^2 = 0.95$; 2004, $y = 117.98x + 1.9278$ $R^2 = 0.98$; 2005) with individual cleistogene seeds counted in 2004 and weighed in 2005.

Soil seedbank was assessed using a 25 mm diameter corer post seedfall during November 2004. Eight samples were taken per measurement transect to 25 mm depth. The cores were combined, homogenised and stored in paper bags. Seed assessments were undertaken on a sample size equivalent to two cores based on volume. Cores were placed in a bucket and sprayed gently with 1-2 litres of water to loosen soil mass and separate any biomass. Each core was then carefully passed through a series of different mesh sized laboratory test sieves (8 mm, 4 mm and 500 μm). Collected biomass from each sieve size was sorted by eye and also under a dissecting microscope to separate any CNG seed from other chaff. Viability was tested by squeezing the seed body under the microscope with tweezers to see and feel whether the seed was filled or unfilled.

6.3.4 Statistical analysis

Measurements were averaged over all quadrats and/or transects, in each separately grazed paddock (or a separate paddock area for the ungrazed control treatment) prior to statistical analysis. The measurements were analysed using a two grazing species (sheep/cattle) by two grazing treatments (set stocked/rotation) factorial plus added control (ungrazed), fully randomised design analysis of variance with separately grazed paddocks as the experimental unit. A number of measurements were transformed prior to statistical analysis, so that the size of the residual variation did not change with the mean value.

6.4 Results

There was little evidence of grazing species by grazing management interactions and thus the results are presented in terms of:

(i) the main effects of grazing species together with their comparison with the ungrazed treatment; and

(ii) the main effects of grazing management.

6.4.1 Effect of grazing on Chilean needle grass seed production

The amount of CNG seed harvested from both the cattle and sheep plots was generally less than the amount of seed harvested from the ungrazed control plots (Table 6.3). During 2004, grazing plots had significantly less standing CNG panicle seeds and stem cleistogenes (both $P = 0.015$). In 2005, grazed plots had less standing panicle seed and stem cleistogene seed although these differences were not significantly different for the two treatments. During the 2004 season, ungrazed plots had up to 74 g panicle seed/m^2 (8,730 panicle seeds/m^2) and 960 cleistogenes/m^2, whilst grazed plots had as low as 4 g panicle seeds/m^2 (472 panicle seeds/m^2) and 230 cleistogenes/m^2. This effect of grazing did not occur to the same degree during the 2005 season. During the 2005 season, grazing only tended to reduce the amount of standing panicle seeds ($P = 0.095$) and did not affect the amount of cleistogenes harvested. Ungrazed plots had 52 g panicle seeds/m^2 (6,235 panicle seeds/m^2) and 1.3 g cleistogenes/m^2. The viability of the panicle seeds harvested from both grazed and ungrazed plots was not significantly different during 2004 (77-82% viable) or 2005 (75-85% viable)(Table 6.3).

6.4.2 Effect of grazing species on Chilean needle grass seed production

Cattle and sheep grazed the CNG with differing intensities over the duration of the trial. During the 2004 season, cattle plots (4 g panicle seed/m^2) tended to have less standing CNG panicle seed than sheep plots (18 g panicle seed/m^2). This trend was not evident for standing panicle seed in the 2005 season (Table 6.3). The amount of cleistogenes harvested in the stems of the CNG and the viability of panicle seeds harvested were not significantly affected by the type of grazer over the 2004 and 2005 seasons. From these results, it can be seen that the cattle are more likely to graze reproductive CNG stalks than the sheep, limiting the production of panicle seeds, as in the 2004 season.. Panicle seed viability, cleistogene production and the CNG soil seedbank were not significantly affected by the type of grazer during 2004 or 2005.

6.4.3 Effect of grazing on pasture production and composition

Average pasture yields were considerably higher in ungrazed plots than grazed plots in October 2004 only (P = 0.039, Table 6.4). By the end of the season in 2004 and 2005 ungrazed plots tended to have more pasture dry matter than grazed plots (P = 0.088; P = 0.072). Pasture regrowth composition in grazed plots had significantly less CNG during December 2004 than pasture regrowth in ungrazed plots. (P = 0.045). This implies that CNG was growing slower than the other pasture species. This observation did not re-occur during the 2005 season. By December in the 2005 season, grazed plots (11%) had significantly more 'other' grasses such as annual grasses than ungrazed plots (0%; P = 0.008). No other categories of pasture regrowth were significantly affected by grazing.

The basal cover of the pasture, during spring 2005, had significantly more broadleaf weed basal cover in grazed (5%) than ungrazed plots (1%)(P = 0.034; spring 2005). No other pasture basal cover classifications were affected by grazing at the time of sampling (Table 6.4).

The amount of available pasture changed between the grazed and ungrazed treatments during the spring seasons of 2004 and 2005. At the start of spring 2004, the available pasture mass was significantly reduced by grazing (2050 kg DM/ha) when compared with ungrazed (4980 kg DM/ha) (P = 0.039). This difference between grazed and ungrazed was reduced by the end of spring, as pasture growth exceeded the grazing ability of the livestock (Table 6.4).

The composition of the pasture regrowth in the grazed and ungrazed plots was affected differently by grazing in each season. By December 2004, the percentage of the pasture that was made up by CNG was significantly lower in grazed plots (43%) than in ungrazed plots (68%; P = 0.045). This implies that CNG was growing slower than the other pasture species. This observation did not re-occur during the 2005 season. By December in the 2005 season, grazed plots (11%) had significantly more 'other' grasses such as annual grasses than ungrazed plots (0%; P = 0.008). No other categories of pasture regrowth were significantly affected by grazing.

6.4.4 Effect of grazing species on pasture production and composition

Plots grazed by the cattle had significantly less vegetative litter basal cover (34%) and significantly more bare soil (8%) than sheep grazed plots during spring 2005 (49% vegetative litter, 0% bare soil; P = 0.005, P = 0.011 respectively)(Table 6.4). Implying that cattle were better able to 'clean up' the pasture although the occurrence of bare soil is not favourable in terms of promoting weed invasion and stimulating CNG seedlings.

The biomass of pasture during the 2004 and 2005 seasons was not significantly affected by the type of grazing species however, the percentage composition of pasture species in the pasture regrowth did differ across the two grazing species during 2004. At October 2005, the perennial grass component of the pasture regrowth in the cattle plots (31.3%) was significantly higher than that in the sheep (16.6%) grazed plots (P = 0.026)(Table 6.4).

6.4.5 Animal production of each grazing species

During September 2004, cattle gained significantly more liveweight (41 kg/ha) than sheep (0 kg/ha; P = 0.015, Table 6.5). This trend did not continue for the remainder of the spring as both species gained similar amounts of liveweight per month. In terms of production potential, as measured by liveweight, both cattle and sheep performed equally.

6.4.6 Effects of grazing management on pasture and Chilean needle grass seed production

Grazing management did not significantly affect the number of panicle seeds, panicle seed viability, number of stem cleistogenes harvested or CNG soil seedbank in 2004 or 2005 (Table 6.6). Pasture basal composition in spring 2005 was also not affected by the different grazing management strategies (Table 6.7). Nor was pasture yield (October and December 2004 & 2005) and the composition of the pasture regrowth (October and December 2004 & 2005) affected by grazing strategy.

6.4.7 Effect of grazing management on animal production

Sheep in the set stock treatment tended to have higher condition scores than sheep in the rotational treatment over spring 2004 (P = 0.090; 3.5 vs 3.2 relatively, Table 6.8). However, this trend did not occur in 2005. Grazing management did not significantly affect the average monthly weight gain in 2004 or 2005 across all livestock.

Table 6.3 Effect of grazing and type of grazer (sheep and cattle) on standing panicle seed, panicle seed viability and stem cleistogenes (s.e.d; Standard Error of Deviation).

Measurement	**Raw or transformed data**				**Back transformed**			**P Value of Control vs. Other**	**P Value of Sheep vs. Cattle**
	Control	**Sheep**	**Cattle**	**s.e.d.**	**Control**	**Sheep**	**Cattle**		
Panicle seed weight g/m^2									
2004 ($\log_{10}$ transformed, initial CNG basal cover covariate)	1.87	1.26	0.57	0.20-0.25	74	18	4	**0.015**	0.064
2005 ($\log_{10}$ transformation)	1.72	1.17	1.11	0.302-0.370	52	15	13	0.147	0.848
Panicle seed viability (%)									
2004	77	82	78	5.5-6.7				0.657	0.522
2005	75	85	84	6.2-7.5				0.239	0.923
Stem cleistogenes									
2004 seed number/m^2 (log transformed)	2.98	2.44	2.37	0.14-0.17	960	280	230	**0.015**	0.615
2005 seed weight (g/m^2)	1.33	0.88	0.98	0.24 – 0.30				0.197	0.684
Soil seedbank									
November 2004 – filled seed/core ($\log_{10}$ transformed)	0.71	0.31	0.11	0.238-0.292	5.1	2.0	1.3	0.120	0.452
% viable Nov 2004 (angular transformed)	19	20	12	16.7-20.4	10	11	4	0.861	0.440

Table 6.4 Effect of grazing and type of grazer (sheep and cattle) on basal pasture composition, pasture yield and pasture regrowth composition (s.e.d; Standard Error of Deviation).

Measurement	**Raw or transformed**				**Back Transformed**			**P Value of Control vs. Other**	**P Value of Sheep vs. Cattle**
	Control	**Sheep**	**Cattle**	**s.e.d.**	**Control**	**Sheep**	**Cattle**		
Basal cover (%) – Spring 2005									
CNG	38	31	30	5.6-6.9				0.294	0.850
Perennial desirable grasses	11	6	11	3.2-3.9				0.649	0.201
Broadleaf weed (spring 2004 broadleaf covariate)	-1	2	5	1.3-1.7				**0.034**	0.179
Other grasses	6	7	11	3.2-3.9				0.420	0.310
Legume (spring 2004 legume covariate)	3	3	4	1.3-1.6				0.901	0.565
Vegetative litter	42	49	34	3.2-3.9				0.900	**0.005**
Bare soil (spring 2004 legume covariate)	1	0	8	1.6-1.9				0.396	**0.011**
Pasture yield (kgDM/ha; log transformed)									
Oct 2004	3.70	3.25	3.37	0.126-0.154	4980	1770	2330	**0.039**	0.385
Dec 2004	3.79	3.52	3.52	0.112-0.137	6120	3340	3330	0.088	0.997
Oct 2005	3.64	3.29	2.70	0.301-0.369	4370	1950	500	0.111	0.108
Dec 2005	3.85	3.43	3.09	0.233-0.285	7080	2690	1230	0.072	0.241
Pasture composition – (%; angular transformed)									
October 2004									
CNG	43.0	34.5	37.4	10.02-12.27	47	32	37	0.561	0.785
Perennial desirable grasses	13.4	15.5	17.3	9.47-11.60	5	7	9	0.790	0.853
Other grasses	28.6	42.0	32.8	11.79-14.45	23	45	29	0.533	0.469
Legumes	10.4	9.7	21.7	6.47-7.93	3	3	14	0.498	0.123
December 2004									

CNG	55.4	41.9	39.8	4.90-6.00	68	45	41	**0.045**	0.688
Perennial desirable grasses	18.8	25.9	24.0	2.85-3.49	10	19	17	0.110	0.517
Other Grasses	19.2	30.7	28.9	6.58-8.06	11	26	23	0.212	0.791
Legumes	7.6	6.9	16.1	6.25-7.65	2	1	8	0.605	0.202
October 2005									
CNG	53.8	54.5	39.6	7.84-9.60	65	66	41	0.476	0.114
Perennial desirable grasses	20.3	16.6	31.3	4.71-5.77	12	8	27	0.517	**0.026**
Other Grasses	4.7	17.1	11.9	6.29-7.70	1	9	4	0.219	0.446
Legumes	0.0	4.4	10.6	3.66-4.48	0	1	3	0.127	0.149
December 2005									
CNG	59.6	53.2	50.9	6.61-8.10	74	64	60	0.354	0.747
Perennial desirable grasses	21.3	15.5	16.9	9.01-11.03	13	7	8	0.633	0.884
Other Grasses	0.0	18.4	20.5	4.10-5.02	0	10	12	**0.008**	0.630
Legumes	0	0	0	-	0	0	0	-	-

Table 6.5 Effect of type of grazer (sheep and cattle) on animal liveweights and condition scores (s.e.d; Standard Error of Deviation).

Measurement	**Control**	**Sheep**	**Cattle**	**s.e.d.**	**P Value of Sheep vs. Cattle**
Weight Change (kg/ha)					
2004					
Sept	-	0	41	10.1	**0.015**
Oct	-	97	92	12.6	0.673
Nov	-	25	33	8.8	0.382
Total Sept – Nov	-	122	166	24.1	0.141
2005 – (sheep only)					
Sept	-	26	-	-	-
Oct	-	9	-	-	-
Nov	-	2	-	-	-
Total Sept – Nov	-	36	-	-	-
Condition score (average of all sheep only)					
Average Spring 2004	-	3.4	-	-	-
Gain Sept – Nov 2004	-	0.5	-	-	-
Dec 2005	-	3.8	-	-	-

Table 6.6 Effect of grazing management (set stock or rotational) by sheep and cattle on standing panicle seed, panicle seed viability and stem cleistogenes (s.e.d; Standard Error of Deviation).

Measurement	**Raw or transformed data**			**Back transformed**		**P Value**
	Set Stock	**Rotation**	**s.e.d.**	**Set Stock**	**Rotation**	
Panicle seed weight g/m^2						
2004 (log transformed, Initial CNG basal cover covariate)	0.73	1.10	0.160	5.3	12.6	0.130
2005 (log transformation)	1.01	1.28	0.302	10	19	0.424
Panicle seed viability (%)						
2004	83	77	5.5			0.340
2005	80	89	6.2			0.219
Stem cleistogenes						
2004 seed numbers/m^2 (log transformed)	2.34	2.47	0.143	220	290	0.418
2005 seed weight (g/m^2)	0.88	0.98	0.242			0.688
Soil seedbank						
November 2004 – Filled seed/core (log transformed)	0.07	0.35	0.238	1.2	2.2	0.289
% viable Nov 2004 (angular transformed)	8.8	22.8	16.68	2	15	0.440

Table 6.7 Effect of grazing management (set stock or rotational) by sheep and cattle on basal pasture composition, pasture yield, and pasture regrowth composition (s.e.d; Standard Error of Deviation).

Measurement	**Raw or transformed data**			**Back transformed**		**P Value**
	Set Stock	**Rotation**	**s.e.d.**	**Set Stock**	**Rotation**	
Basal cover (%) – Spring 2005						
CNG	31	29	5.6			0.721
Perennial desirable grasses	7	11	3.2			0.233
Broadleaf Weed (Spring 2004 broadleaf covariate)	3	4	1.2			0.449
Other Grasses	9	9	3.2			0.955
Legume (Spring 2004 legume covariate)	3	3	1.2			0.905
Vegetative litter	41	43	3.2			0.617
Bare Soil (Spring 2004 legume covariate)	5	3	1.4			0.151
Pasture yield (kgDM/ha; log transformed)						
Oct 2004	3.25	3.36	0.126	1790	2290	0.439
Dec 2004	3.57	3.48	0.112	3720	3000	0.443
Oct 2005	3.03	2.95	0.301	1070	890	0.810
Dec 2005	3.07	3.46	0.233	1170	2880	0.155
Pasture yield composition – (%; Angular transformed)						
October 2004						
CNG	33.2	38.7	10.02	30	39	0.607
Perennial desirable grasses	19.4	13.4	9.47	11	5	0.549
Other grasses	37.5	37.2	11.79	37	37	0.982
Legumes	16.8	14.7	6.47	8	6	0.756
December 2004						
CNG	40.7	41.0	4.90	43	43	0.951
Perennial desirable grasses	26.5	23.4	2.85	20	16	0.324

Other grasses	25.0	34.5	6.58	18	32	0.210
Legumes	15.4	7.6	6.25	7	2	0.267
October 2005						
CNG	50.9	43.2	7.84	60	47	0.375
Perennial desirable grasses	21.8	26.2	4.71	14	19	0.393
Other grasses	11.6	17.5	6.29	4	9	0.394
Legumes	9.8	5.1	3.66	3	1	0.257
December 2005						
CNG	52.0	52.0	6.61	62	62	0.996
Perennial desirable grasses	12.7	19.7	9.01	5	11	0.473
Other grasses	20.5	18.4	4.10	12	10	0.633
Legumes	0	0	-	0	0	-

Table 6.8 - Effect of grazing management (set stock or rotational) by sheep and cattle on animal liveweights and condition scores (s.e.d; Standard Error of Deviation).

Measurement	**Set Stock**	**Rotation**	**s.e.d.**	**P Value**
Weight change (kg/ha)				
2004				
Sept	26	15	10.1	0.338
Oct	97	92	12.57	0.714
Nov	29	29	8.8	0.945
Total Sept – Nov	152	136	24.1	0.560
***2005** – (sheep only)*				
Sept	28	24	9.4	0.736
Oct	3	15	8.6	0.299
Nov	2	1	13.4	0.953
Total Sept – Nov	33	40	5.9	0.336
Condition score				
(average of all sheep only)				
Average Spring 2004	3.5	3.2	0.10	0.090
Gain Sept – Nov 2004	0.3	0.8	0.64	0.513
Dec 2005	3.7	4.0	0.30	0.497

6.5 Discussion

The occurrence of CNG impacts adversely on several aspects of agricultural production, such as replacing desirable species and the downgrading of livestock produce. Since the panicle seeds of CNG are adapted for attachment to moving objects, the choice of grazing species and their ability to utilise and suppress this weed needs to be considered in grazing systems (Gardener *et al.* 2003a).

6.5.1 Effect of grazing on Chilean needle grass seed production

Grazing was able to reduce the amount of standing CNG panicle and cleistogene seed present at the time of seed set. Although this result is statistically significant, its practicality as a management strategy to reduce further spread of CNG or to improve animal welfare, is limited. The ungrazed panicle seed harvested from grazing plots (4 g) represented 472 seeds/m^2, which is a high risk for further weed spread.

6.5.2 Effect of grazing species on pasture and Chilean needle grass seed production

Cattle are known to be less selective grazers than sheep (Friend and Kemp 2000). The findings from this trial support this statement as the cattle were better able to 'clean up' the pasture than sheep, by grazing reproductive CNG stalks, whilst also reducing vegetative litter cover which effectively increased the amount of bare soil. Possibly caused by sheep leaving more residual pasture that becomes vegetative litter. Cattle grazing, and the ability to graze evenly encouraged perennial desirable grass growth in the 2005 season (cattle plots 31.3%, sheep plots 16.6%). These findings suggest that cattle grazing is preferential for reducing CNG seed, however they are more likely to create gaps in the pasture, caused by bare areas, that can encourage CNG seedlings. Goats were not used in this experiment due to an inability to site goats in an existing sheep and cattle grazing system with sufficient scale/farm size to provide meaningful results.

6.5.3 Effect of grazing management on Chilean needle grass seed production

The use of a four paddock grazing rotation based on a 12DSE/ha stock rate (48DSE/ha peak stock rate) was not sufficient to reduce the amount of CNG seed produced when compared with set stocked plots in this trial. Grazing management did not significantly affect the number of panicle seeds, panicle seed viability or number of stem cleistogenes harvested in 2004 and 2005.

Given the late spring growth flushes during spring 2004 and 2005, related to rainfall (Table 6.1), the grazing could not get ahead of the pasture and reduce the pasture mass, even in the rotational plots. It was observed that the window of opportunity for grazing CNG to reduce seedheads was approximately 2 weeks (from seed head development to seed head emergence – based on observations at times of stock rotations). After this time stock (both sheep and cattle) were reluctant to graze CNG reproductive tillers and they were able to produce seed. From these observations, it could be concluded that rotational grazing will not be useful as a management strategy to reduce CNG seed production if the infestation represents more area than can be grazed in the 2 week window between seedhead development and emergence. For rotational grazing to be beneficial, the rotation needs to be timed such that the active grazing cell begins in the infested area at the time of seedhead development – therefore grazing the CNG stems prior to seedhead development. The stock rate of the grazing cells may have had some influence in terms of the grazing pressure placed on the CNG. An increased stock rate may cause the grazing of more CNG, although given the constraints of carrying more stock all year, a higher stocking rate may be better achieved by having smaller grazing cells rather than a higher overall stocking rate.

6.5.4 Effect of grazing and grazing management on pasture production and composition

The rate of CNG growth, measured as a proportion of total pasture mass, was significantly reduced in the plots that had been grazed over 2004. This result is similar to findings from grazing work undertaken in the New England Tablelands (MLA 2003) where CNG pasture proportion declined under rotational grazing. In contrast, pasture basal composition in spring 2005 was not affected by the different grazing management strategies. Pasture yield (October and December 2004 & 2005) and the composition of the pasture regrowth (October and December 2004 & 2005) was also not affected by the grazing management. These results imply that the stock rate and manipulation of grazing was not detrimental to the pasture basal composition. However, the result was not as expected as CNG is said to have a relatively slow growth rate compared with faster growing perennial grasses such as tall fescue (*Festuca arundinacea*) cocksfoot (*Dactylis glomerata*) (MLA 2003; WeedsCRC 2001). In contrast to findings at Ashley park (MLA 2003), NSW Northern Tablelands, rotational grazing with a 55 day effective rest period, did not provide any pasture regrowth composition advantages at this site over spring 2004 and spring 2005. These findings may be attributed to the predominantly winter rainfall pattern of southern Australia in comparison with the summer rainfall patterns of the New England Tablelands.

6.5.5 Animal production of each grazing species and effects of grazing management

Grazing management did not significantly affect the average monthly weight gain in 2004 and 2005 across all livestock. In terms of production potential, both cattle and sheep performed equally. When the risk of panicle seed spread by fleece contamination is considered, together with the risk to animal welfare (Gardener 1998; Gardener *et al.* 2003a), sheep cannot be considered a suitable species for grazing CNG. Sheep fleeces were extremely contaminated by CNG panicle seeds whereas cattle would occasionally have a maximum of 10 seeds on their backline.

6.6 Conclusion

Grazing significantly reduced the amount of standing CNG panicle and cleistogene seeds during the 2004 season yet this did not occur in 2005 (from 8,730 seeds/m^2 to 472 seeds/m^2; 2004). Grazing left sufficient seed to pose a risk to further weed spread.

Plots that had been grazed had significantly more broadleaf weeds than ungrazed plots in 2005. No other basal cover classifications were affected by grazing. Grazing was able to reduce the pasture mass in early spring (12 DSE/ha), however by the end of spring pasture growth was exceeding the rate of grazing. Regrowth in grazed areas did have less CNG during spring 2004, but not in 2005.

Cattle are better suited to grazing CNG as they grazed more CNG panicle seedheads than sheep during 2004 (in 2005 the result was not significant due to high variability in the data). However, cattle plots had more bare soil with a greater percentage of desirable perennial grass regrowth than sheep plots.

Cattle gained significantly more liveweight than sheep during early spring 2004 although overall both species performed equally in terms of weight gain for the remainder of the trial.

Grazing management, based on a four paddock rotation with the CNG infestation being spread across the whole grazing area, did not provide any gains in terms of standing CNG panicle seed, panicle seed viability or stem cleistogenes harvested. Grazing management also did not affect the basal cover of the different pasture classifications, the pasture yield, or the composition of the pasture regrowth.

6.6.1 Future studies

From the results of this experiment, future studies need to focus on use of cattle at higher stocking rates in managed grazing systems to maximise utilisation whilst minimising seed head production of CNG. The use of goats should also be considered. Given that CNG is distributed across different climatic regions, the growth rate of CNG in comparison with other desirable pasture grasses in these zones needs to be monitored as an outcome of rotational grazing. Implementation of alternative means of reducing seedhead production, in areas that cannot be grazed prior to seedhead emergence, also requires investigation to enable better weed management.

Chapter 7 Conclusion

This thesis was undertaken to identify long term control and appropriate grazing management strategies that both suppressed and better utilised CNG. The hypothesis to be tested in this thesis is that CNG can be utilised through grazing for both animal production and to reduce its populations in agricultural situations. Trials were conducted across the known range of CNG, to discover how to maximise the usefulness of this plant for animal production while at the same time keeping it in check.

7.1 Key findings

- CNG can be utilised by grazing stock when it is vegetative during the cooler winter months, but its palatability is still below that of *Dactylis glomerata.*
- Both CNG and *Phalaris aquatica* respond to increased phosphorus similarly.
- Conventional cropping in the Northern NSW region was successful in reducing CNG infestations.
- Set stocking and flupropanate leads to more bare ground and increased CNG cover.
- Once CNG becomes reproductive, stock avoid eating it, even at stocking rates of 300 DSE/ha.
- Cattle are less likely to be contaminated by panicle seed than sheep when grazing CNG.
- Rotational grazing has a limited window of opportunity to reduce standing panicle seed.

7.2 Implications for CNG management

Based on recommendations from previous studies and experiences in managing CNG, this PhD has focussed on longterm utilisation and control of CNG (Gardener 1998; Lowien 2002). The findings of the PhD can be applied in several management contexts, ranging from summer rainfall dominant (northern) to winter rainfall dominant (southern) districts, taking in both grazing and ungrazed production systems, as well as summer rainfall cropping systems. Some of the land management contexts and how the findings can be applied are discussed below.

7.2.1 Grazing

Feed value and weed hygiene

When considering grazing livestock on areas infested with CNG, the seasonal fluctuations of feed value and the physical risk of CNG panicle seeds need to be considered. The feed value of CNG is generally lower than that of other production grasses such as *Dactylis glomerata* which is only considered of moderate feed value. However, at certain times of year the feed value of CNG is well below acceptable levels. These periods are mostly aligned to when CNG becomes reproductive and during seeding periods when there is also the physical risk of CNG seed dispersal via animals and machinery. CNG seed is also able to contaminate fleeces and carcasses. Once CNG has become reproductive, it will not be grazed by stock even at rates as high as 300 DSE/ha. This grazing pressure leads to overgrazing of desirable pasture species while the sharp pointed seeds of CNG present an animal welfare issue, particularly to sheep.

Choice of grazer

Livestock are a major vector for spreading CNG panicle seeds. Often CNG infestations within farms have clearly been spread from livestock grazing into adjoining roadsides or along infested waterways. Grazing can be used as a means to reduce the seed production of CNG although the choice of grazer and timing of grazing is critical.

Assessments undertaken during this study have clearly shown that cattle are more suited to grazing CNG than sheep. Sheep in full fleece are more likely to be contaminated by CNG panicle seeds than cattle. The welfare and production concerns for sheep grazing CNG, such as meat and fleece contamination and risk of spread of seed over the following months, continue even after shearing. Cattle are more suited to grazing CNG as their coats are less likely to become contaminated by CNG panicle seed than the fleece of sheep, and cattle tend to graze more panicle seed than sheep. Cattle have a reduced risk of further weed spread and have improved animal welfare levels.

Managing grazing

High intensity grazing (i.e. rotational grazing/strategic grazing) can be used to reduce the production of CNG panicle seeds. High intensity grazing requires high stocking rates (up to 300 DSE/ha) to reduce the pasture mass to threshold levels (~1000 kgDM/ha). Grazing should be managed in CNG infestations prior to seedhead emergence to reduce the amount of seed produced by CNG. If the pastures are grazed too early, some CNG seedhead regeneration may occur. Grazing CNG pastures after seed head emergence encourages selective grazing and tends to place additional grazing pressure on desirable species rather than CNG. Given that CNG is known to regenerate a seedhead in a short period of time (approximately 2 weeks), using rotational grazing of pastures is only effective if the entire CNG infestation can be grazed prior to panicle seed emergence. CNG infested areas that cannot be grazed prior to panicle seed emergence should be managed as part of an integrated weed strategy to reduce seed production. Management by other means such as spraytopping (Gaur *et al.* 2005), burning (Grech *et al.* 2004; Grech and McLaren 2005b), slashing (Grech *et al.* 2004; Grech and McLaren 2005b) and wiping (Grech *et al.* Unpublished 2006) are all effective methods.

7.2.2 Pasture renovation and cropping

Choice of herbicide and follow up management

Flupropanate based herbicides were effective in reducing the initial level of CNG basal cover across all sites although there was some damage to desirable species. Set stock grazing of flupropanate sprayed plots increased bare ground and generally led to broadleaf weed and CNG reinvasion within 2 years.

Areas that have been sprayed with flupropanate herbicides to reduce CNG infestations should therefore be strategically grazed or locked up so as to achieve long rest periods between grazing and ensure that ground cover is maintained and that desirable species recover.

The use of flupropanate at Glen Innes gave a better result than in the southern trial sites. Flupropanate can be used to selectively kill CNG without affecting desirable grasses although these plots had increased bare ground and generally led to broadleaf weed invasion.

Glyphosate based herbicides should only be used to control CNG as part of a weed management strategy that involves planting replacement species. Where glyphosate was applied without follow up management, or sufficient pasture competition from resown grasses, CNG quickly re-invaded. The ability of resown grasses to compete and inhibit the re-invasion of CNG depends on seasonal conditions within the district.

Choice of pasture renovation strategy

Resowing of pasture directly into CNG sprayed out with glyphosate was not successful. CNG re-invading the pasture was able to outcompete the sown species – regardless of district specific pasture seed recommendations. Without the use of a soil residual chemical, or other means of suppressing the CNG soil seedbank, resowing a pasture into a sprayed CNG infestation would seem useless during dry seasons where limited pasture competition could be achieved.

The use of annual cropping in the northern district was successful at suppressing the CNG soil seedbank. Mechanical and chemical fallows associated with summer cropping and winter cropping are proving to be useful tools to suppress CNG seedlings at critical stages.

Although the correction of soil pH or increased soil phosphorus encouraged the growth of CNG and *Phalaris aquatica*, by maturity CNG had the larger response, indicating the use of increased phosphorus with phalaris may not be useful of itself in generating increased plant growth responses against CNG.

7.3 Future work

The effect of flupropanate in different soil types and its residual ability for CNG is not well documented. This topic area and the effect of flupropanate on off target species needs to be further investigated in different soil types and climatic zones. Other methods of seedbank destruction and seedhead avoidance such as burning, slashing, herbicide wiping and spraytopping, could form part of an integrated weed management strategy for CNG, and need further investigation. The use of cropping in the context of different regions and the ability to use alternative herbicides to control CNG is also a major gap in the knowledge of how to control CNG. The use of other grass selective herbicides and alternative herbicide groups may be extremely useful when integrated with broadleaf or forage crops.

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Chilean needle grass field day (NHT, CRC and City of Whittlesea), Greenvale, VIC, November 2005

Pasture, Grazing and Grass field day (NHT, CRC, NMIT and City of Whittlesea), Whittlesea 3 December 2006

Appendices

Table A3.1 Effect of Clipping on the feedvalue of CF and CNG.

Measurement	CF		CNG		s.e.d.			P Value		
	Unclipped (a)	Clipped (b)	Unclipped (c)	Clipped (d)	(a) vs (c)	(b) vs (d)	Other	Species	Clipping	Species by clipping interaction
Crude Protein (%DM)										
Sept 2003	15.8	13.9	13.7	13.1	0.86	0.43	1.01	**0.017**	0.195	0.236
Oct 2003	12.1	17.6	10.7	15.2	1.31	0.65	1.02	**0.0034**	**0.00011**	0.531
Nov 2003	7.3	16.9	7.6	12.5	1.09	0.54	0.92	**0.000030**	**6.3 x10^{-6}**	**0.0029**
Dec 2003	6.3	16.1	6.3	12.3	0.90	0.45	0.74	**0.000019**	**4.5 x10^{-7}**	**0.0038**
May 2004	16.7	22.7	13.1	18.3	1.39	0.70	1.15	**0.000043**	**0.00016**	0.608
Sept 2004	14.1	19.2	11.6	17.4	0.95	0.48	1.04	**0.00089**	**0.00027**	0.560
Oct 2004	8.7	14.6	8.2	12.1	0.99	0.50	0.68	**0.00062**	**1.9 x 10^{-6}**	0.094
Dec 2004	6.7	13.3	5.0	9.2	0.89	0.60	0.67	**3.9 x10^{-6}**	**1.9 x10^{-6}**	**0.032**
Sept 2005	10.8	17.2	6.5	9.8	1.39	0.70	1.08	**7.2 x10^{-7}**	**0.00017**	0.077
Metabolisable Energy (MJ/KgDM)										
Sept 2003	10.4	10.0	8.9	8.7	0.27	0.14	0.25	**6.2 x10^{-7}**	0.118	0.562
Oct 2003	9.8	10.3	8.2	9.0	0.27	0.14	0.21	**5.6 x10^{-7}**	**0.0019**	0.442
Nov 2003	7.9	10.2	7.3	8.5	0.27	0.13	0.23	**2.3 x10^{-7}**	**0.000014**	**0.0040**
Dec 2003	7.6	10.0	6.6	8.4	0.30	0.15	0.26	**9.0 x10^{-7}**	**6.0 x10^{-6}**	0.123
May 2004	8.4	9.5	7.5	9.0	0.30	0.15	0.24	**0.0028**	**0.000063**	0.233
Sept 2004	8.7	9.7	7.8	9.3	0.20	0.10	0.26	**0.00012**	**0.00063**	0.057
Oct 2004	7.9	9.5	7.4	8.4	0.18	0.09	0.19	**2.3 x10^{-7}**	**0.000042**	**0.0083**
Dec 2004	6.6	8.7	5.3	6.9	0.16	0.08	0.20	**4.1 x10^{-10}**	**6.2 x10^{-6}**	**0.017**
Sept 2005	7.6	9.4	6.1	8.2	0.32	0.16	0.24	**6.4 x10^{-6}**	**1.8 x10^{-6}**	0.421
Neutral Detergent Fibre (%DM)										
Sept 2003	57.0	59.8	62.3	63.0	1.83	0.92	1.91	**0.0012**	0.312	0.329
Oct 2003	61.8	59.4	67.1	64.1	1.48	0.74	1.15	**0.000026**	**0.011**	0.724
Nov 2003	68.6	60.1	73.3	68.0	1.52	0.76	1.24	**8.6 x10^{-7}**	**0.000062**	0.087
Dec 2003	73.2	67.5	68.8	63.0	1.14	0.57	1.04	**5.1 x10^{-6}**	**0.00012**	0.992
May 2004	71.5	59.9	76.0	63.9	1.81	0.90	1.57	**0.00046**	**9.4 x10^{-6}**	0.822
Sept 2004	65.3	55.6	71.3	56.8	1.40	0.70	1.52	**0.0070**	**0.000014**	**0.012**
Oct 2004	72.0	61.0	74.0	65.5	1.07	0.54	1.01	**8.7 x10^{-6}**	**2.2 x10^{-6}**	0.063
Dec 2004	75.9	66.3	80.2	74.4	0.75	0.38	0.85	**8.7 x10^{-10}**	**6.4 x10^{-6}**	**0.00097**
Sept 2005	69.1	57.7	76.0	66.4	1.63	0.82	1.10	**4.9 x10^{-7}**	**1.3 x10^{-7}**	0.344

Digestible Dry Matter (%DM)										
Sept 2003	71.7	68.9	62.3	60.6	1.73	0.86	1.56	**6.7×10^{-7}**	0.100	0.573
Oct 2003	67.4	70.7	57.6	62.4	1.64	0.82	1.27	**3.7×10^{-7}**	**0.0019**	0.437
Nov 2003	56.0	70.1	52.3	59.5	1.68	0.84	1.48	**2.4×10^{-7}**	**0.000014**	**0.0041**
Dec 2003	53.9	68.9	47.7	59.1	1.91	0.96	1.65	**9.3×10^{-7}**	**6.0×10^{-6}**	0.125
May 2004	58.6	65.4	53.3	62.8	1.85	0.92	1.47	**0.0034**	**0.000052**	0.221
Sept 2004	61.0	67.4	55.1	64.4	1.29	0.64	1.59	**0.00011**	**0.00054**	0.070
Oct 2004	55.9	65.8	52.7	58.8	1.10	0.55	1.16	**1.8×10^{-7}**	**0.000037**	**0.011**
Dec 2004	47.1	60.6	39.4	49.3	0.97	0.49	1.20	**3.14×10^{-10}**	**4.5×10^{-6}**	**0.0082**
Sept 2005	54.1	65.0	44.5	57.8	2.03	1.01	1.52	**6.9×10^{-6}**	**2.2×10^{-6}**	0.331
Dry Matter (%Fresh Wt)										
Sept 2003	28.6	28.4	43.4	42.7	2.35	1.18	1.71	**8.2×10^{-8}**	0.683	0.881
Oct 2003	28.3	25.0	36.8	31.1	1.01	0.51	1.30	**4.3×10^{-8}**	**0.0049**	0.064
Nov 2003	42.9	29.6	48.7	38.3	2.42	1.21	1.99	**0.000021**	**0.000040**	0.316
Dec 2003	51.7	42.1	61.7	53.5	2.80	1.40	2.83	**4.8×10^{-6}**	**0.0055**	0.669
May 2004	29.3	26.6	45.5	39.7	1.84	0.92	2.16	**1.3×10^{-8}**	0.055	0.160
Sept 2004	31.7	27.0	46.6	38.2	2.25	1.12	2.52	**3.2×10^{-7}**	**0.016**	0.167
Oct 2004	29.8	26.5	42.5	30.0	1.20	0.60	1.34	**1.7×10^{-6}**	**0.00014**	**0.000048**
Dec 2004	35.1	27.2	43.8	35.6	0.93	0.47	1.10	**1.7×10^{-9}**	**0.000033**	0.861
Sept 2005	47.7	34.9	68.1	55.4	3.08	1.54	2.11	**3.7×10^{-8}**	**6.0×10^{-6}**	0.954

Table A3.2 Effect of nitrogen fertiliser and clipping on the feedvalue of CF and CNG.

Measurement	CF		CNG		s.e.d.		P Value	
	Clipped no nitrogen (a)	**Clipped with nitrogen (b)**	**Clipped no nitrogen (a)**	**Clipped with nitrogen (b)**	**(a) vs (b)**	**other**	**Nitrogen application**	**Species by nitrogen interaction**
Crude Protein (%DM)								
Sept 2003	14.8	13.1	13.1	13.1	0.90	0.61	0.329	0.083
Oct 2003	15.8	19.4	15.0	15.3	0.91	0.92	**0.014**	**0.028**
Nov 2003	14.8	19.1	11.0	14.1	0.83	0.77	**0.00034**	0.303
Dec 2003	14.4	17.8	11.9	12.7	0.66	0.64	**0.0022**	**0.014**
May 2004	23.2	22.3	17.9	18.7	1.03	0.99	0.957	0.273
Sept 2004	19.4	19.1	17.0	17.8	0.93	0.67	0.769	0.326
Oct 2004	14.7	14.6	11.8	12.3	0.61	0.70	0.506	0.580
Dec 2004	13.0	13.7	9.5	9.0	0.60	0.63	0.824	0.191
Sept 2005	18.6	15.9	9.8	9.9	0.96	0.99	0.091	0.077
Metabolisable Energy (MJ/KgDM)								
Sept 2003	10.2	9.8	8.7	8.7	0.22	0.19	0.378	0.298
Oct 2003	10.0	10.5	8.9	8.9	0.19	0.19	0.051	0.113
Nov 2003	9.8	10.6	8.2	8.8	0.21	0.19	**0.0019**	0.614
Dec 2003	9.6	10.4	8.3	8.6	0.24	0.21	**0.018**	0.130
May 2004	9.6	9.3	9.1	8.9	0.21	0.21	0.178	0.787
Sept 2004	9.7	9.8	9.2	9.4	0.23	0.14	0.638	0.522
Oct 2004	9.5	9.5	8.2	8.6	0.17	0.13	0.274	**0.039**
Dec 2004	8.6	8.8	7.0	6.8	0.18	0.11	0.919	**0.016**
Sept 2005	9.5	9.3	8.3	8.2	0.21	0.23	0.272	0.483
Neutral Detergent Fibre (%DM)								
Sept 2003	59.1	60.5	62.4	63.6	1.71	1.29	0.388	0.859
Oct 2003	60.6	58.2	64.0	64.2	1.03	1.04	0.165	0.104
Nov 2003	62.6	57.6	70.0	66.1	1.11	1.08	**0.00059**	0.087
Dec 2003	65.0	61.1	68.3	66.8	0.93	0.81	**0.0063**	0.071
May 2004	59.0	60.8	62.4	65.5	1.40	1.28	0.053	0.478
Sept 2004	55.5	55.8	57.5	56.0	1.36	0.99	0.630	0.211
Oct 2004	60.8	61.2	66.5	64.5	0.91	0.76	0.306	0.052
Dec 2004	66.7	66.0	74.0	74.9	0.76	0.53	0.912	0.061
Sept 2005	56.3	59.2	66.4	66.3	0.98	1.15	**0.037**	0.094

Sept 2003	70.0	67.9	60.7	60.6	1.39	1.22	0.375	0.301
Oct 2003	69.5	72.3	62.3	62.5	1.14	1.16	0.061	0.094
Nov 2003	67.5	72.6	57.4	61.6	1.32	1.18	**0.0019**	0.621
Dec 2003	66.5	71.4	58.3	60.0	1.48	1.35	**0.018**	0.130
May 2004	66.3	64.6	63.4	62.2	1.31	1.31	0.165	0.799
Sept 2004	67.3	67.4	64.0	64.9	1.42	0.91	0.694	0.501
Oct 2004	65.8	65.8	57.6	60.1	1.04	0.78	0.203	**0.040**
Dec 2004	59.8	61.4	50.0	48.6	1.08	0.69	0.940	**0.012**
Sept 2005	66.0	64.0	57.9	57.7	1.36	1.43	0.245	0.387
Dry Matter (%Fresh Wt)								
Sept 20030	28.1	28.6	42.6	42.9	1.53	1.66	0.705	0.919
Oct 200337	25.7	24.2	31.6	30.7	1.16	0.72	0.271	0.546
Nov 200363	29.7	29.5	37.8	38.7	1.78	1.71	0.756	0.666
Dec 200378	43.1	41.1	53.5	53.5	2.53	1.98	0.649	0.492
May 2004	26.5	26.7	39.3	40.1	1.93	1.30	0.766	0.772
Sept 2004	26.7	27.3	38.3	38.0	2.25	1.59	0.941	0.722
Oct 2004	26.3	26.8	29.9	30.2	1.20	0.85	0.702	0.877
Dec 2004	27.5	26.9	36.2	35.1	0.98	0.66	0.366	0.627
Sept 2005	33.1	36.6	54.4	56.4	1.89	2.18	0.081	0.620

Table A3.3 Effect of phosphorus fertiliser on combined feedvalues (CF and CNG).

Measurement	No phosphorus clipped	Phosphorus clipped	s.e.d.	P Value
Crude Protein (%DM)				
Sept 2003	12.4	14.6	0.79	**0.024**
Oct 2003	17.0	15.8	0.64	0.093
Nov 2003	15.2	14.2	0.62	0.144
Dec 2003	14.0	14.3	0.48	0.553
May 2004	20.3	20.7	0.76	0.663
Sept 2004	18.6	18.1	0.79	0.566
Oct 2004	13.8	12.9	0.36	**0.027**
Dec 2004	11.3	11.3	0.40	0.919
Sept 2005	13.0	14.0	0.66	0.167
Metabolisable Energy (MJ/KgDM)				
Sept 2003	9.03	9.63	0.179	**0.010**
Oct 2003	9.66	9.58	0.126	0.502
Nov 2003	9.36	9.31	0.163	0.748
Dec 2003	9.14	9.29	0.180	0.441
May 2004	9.24	9.22	0.153	0.874
Sept 2004	9.54	9.48	0.205	0.753
Oct 2004	8.97	8.92	0.142	0.734
Dec 2004	7.74	7.79	0.159	0.761
Sept 2005	8.72	8.90	0.141	0.230
Neutral Detergent Fibre (%DM)				
Sept 2003	63.5	59.3	1.44	**0.020**
Oct 2003	61.5	62.0	0.72	0.506
Nov 2003	63.6	64.6	0.81	0.257
Dec 2003	65.6	65.0	0.73	0.456
May 2004	61.5	62.3	1.07	0.514
Sept 2004	56.1	56.3	1.16	0.846
Oct 2004	63.0	63.5	0.73	0.474
Dec 2004	70.4	70.3	0.66	0.951
Sept 2005	62.7	61.4	0.54	**0.049**
Digestible Dry Matter (%DM)				
Sept 2003	62.9	66.6	1.09	**0.010**
Oct 2003	66.8	66.2	0.79	0.457
Nov 2003	65.0	64.6	1.02	0.752
Dec 2003	63.6	64.5	1.13	0.440
May 2004	64.2	64.1	0.93	0.952
Sept 2004	66.1	65.7	1.27	0.741
Oct 2004	62.5	62.2	0.88	0.727
Dec 2004	54.8	55.1	0.96	0.719
Sept 2005	60.8	62.0	0.90	0.227
Dry Matter (%fresh Wt)				
Sept 2003	37.6	33.5	0.98	**0.0028**
Oct 2003	28.0	28.1	1.05	0.898
Nov 2003	32.2	35.6	1.31	**0.033**
Dec 2003	48.5	47.1	2.10	0.537
May 2004	34.2	32.2	1.70	0.280
Sept 2004	32.6	32.5	1.95	0.952
Oct 2004	28.8	27.7	1.04	0.305
Dec 2004	31.6	31.2	0.87	0.623
Sept 2005	46.2	44.1	1.09	0.081

Table A4.1 Seedling and mature phase measurement dates (2005).

Experimental day	Seedling	Mature
5	18th July	18th July
12	25th July	25th July
19	1st August	1st August
28	10th August	10th August
33	15th August	15th August
40	22nd August	22nd August
54	n/a	5th September
63	n/a	14th September
68	n/a	19th September
75	n/a	26th September
84	n/a	5th October
89	n/a	10th October
104	n/a	25th October
120	n/a	10th November
148	n/a	8th December
162	n/a	22nd December

Table A4.2 Effect of species (CNG and Phalaris) and phosphorus on seedling shoot weight, root length and root to shoot ratio at harvest (No nitrogen treatments).

Measurement	**Chilean needle grass**		**Phalaris**		**s.e.d.**			**P Values**		
	No P added (a)	P added (b)	No P added (a)	P added (b)	(a) vs (b)	(a) vs (a)	(b) vs (b)	Species Main Effect	Difference between P added and no P added	P Value for the difference between P added and no P added differing with species
Shoot Wt – Log (x + 0.01)	-1.44	-0.94	-1.47	-0.58	0.082	0.095	0.067	**0.000059**	**1.8×10^{-21}**	**0.0015**
Backtransformed (grams)	0.03	0.11	0.02	0.25	-	-	-			
Leaf area – Log (x + 0.025)	0.94	1.37	1.09	1.92	0.070	0.081	0.058	**2.42×10^{-14}**	**7.8×10^{-23}**	**0.00014**
Backtransformed (cm^2)	4	19	7	78	-	-	-			
Root Length (cm)	25.7	28.9	16.9	35.4	3.07	3.54	2.50	0.507	**2.2×10^{-6}**	**0.00066**
Root Wt - Log (x + 0.025)	-1.07	-0.82	-1.24	-0.50	0.074	0.085	0.060	**0.0014**	**8.8×10^{-16}**	**6.6×10^{-6}**
Backtransformed (grams)	0.06	0.13	0.03	0.29	-	-	-			
Root:Shoot – Log (x)	0.37	0.08	0.13	0.06	0.088	0.102	0.072	0.138	**0.0044**	0.072
Backtransformed	2.4	1.2	1.4	1.2	-	-	-			

Table A4.3 Effect of species (CNG vs Phalaris) & soil pH on seedling shoot weight, leaf area, root length, root weight and root to shoot ratio at harvest (No nitrogen treatments).

Measurement	**Chilean needle grass**			**Phalaris**			**s.e.d.**	**P-Values**	
	pH 5	pH 7	pH 9	pH 5	pH 7	pH 9		pH (both species)	Species by pH Interaction
Shoot Wt – Log (x + 0.01)	-1.11	-1.05	-1.16	-0.91	-0.77	-0.95	0.095	0.097	0.806
Backtransformed (grams)	0.07	0.08	0.06	0.11	0.16	0.10	-		
Leaf area – Log (x + 0.025)	1.20	1.30	1.18	1.60	1.75	1.59	0.081	**0.033**	0.895
Backtransformed (cm^2)	11	15	10	34	51	34	-		
Root Length (cm)	27.5	30.5	25.6	29.2	31.5	26.9	3.54	0.163	0.991
Root Wt - Log (x + 0.025)	-0.89	-0.86	-0.95	-0.74	-0.66	-0.83	0.085	0.106	0.801
Backtransformed (grams)	0.10	0.11	0.09	0.16	0.19	0.12	-		
Root:Shoot – Log (x)	0.20	0.16	0.17	0.15	0.06	0.06	0.102	0.592	0.922
Backtransformed	1.6	1.4	1.5	1.4	1.1	1.2	-		

Table A4.4 Effect of species (CNG and Phalaris) and phosphorus on seedling shoot height during the growing period (No nitrogen treatments).

Measurement	**Chilean needle grass**		**Phalaris**		**s.e.d.**			**P Values**		
	No P added (a)	P added (b)	No P added (a)	P added (b)	(a) vs (b)	(a) vs (a)	(b) vs (b)	Species Main Effect	Difference between P added and no P added	P Value for the difference between P added and no P added differing with species
Seedling Ht (cm)										
d5 (log)	0.95	0.96	0.84	0.88	0.019	0.022	0.016	**4.7×10^{-10}**	0.068	0.223
d5 Backtransformed	9.0	9.2	6.9	7.7	-	-	-			
d12 (log)	0.95	1.01	0.86	0.95	0.023	0.027	0.019	**0.000013**	**0.000036**	0.272
d12 Backtransformed	9.0	10.1	7.2	8.9	-	-	-			
d19 (log)	1.04	1.11	0.93	1.16	0.024	0.028	0.019	0.966	**9.9×10^{-15}**	**1.2×10^{-6}**
d19 Backtransformed	11.0	12.7	8.4	14.6	-	-	-			
d26 (log)	1.06	1.24	0.97	1.34	0.033	0.038	0.027	0.071	**6.4×10^{-21}**	**3.4×10^{-5}**
d26 Backtransformed	11.5	17.2	9.3	22.0	-	-	-			
d33 (log)	1.06	1.26	1.01	1.42	0.034	0.039	0.028	**0.00018**	**4.7×10^{-23}**	**3.0×10^{-5}**
d33 Backtransformed	11.4	18.3	10.1	26.3	-	-	-			
d40 (log)	1.12	1.36	1.10	1.50	0.038	0.044	0.031	**0.0011**	**1.7×10^{-21}**	**0.0034**
d40 Backtransformed	13.2	23.3	12.5	32.0	-	-	-			

Table A4.5 Effect of species (CNG and Phalaris) & soil pH on seedling height during the growing period (No nitrogen treatments).

Measurement	**Chilean needle grass**			**Phalaris**			**s.e.d.**	**P-Values**	
	pH 5	pH 7	pH 9	pH 5	pH 7	pH 9		pH (both species)	Species by pH Interaction
Seedling Ht (cm)									
d5 (log)	0.96	0.96	0.96	0.85	0.88	0.88	0.023	0.575	0.468
d5 Backtransformed	9.1	9.0	9.1	7.1	7.5	7.7	-		
d12 (log)	0.99	0.99	0.99	0.89	0.94	0.92	0.027	0.315	0.340
d12 Backtransformed	9.7	9.8	9.7	7.7	8.8	8.4	-		
d19 (log)	1.10	1.09	1.06	1.07	1.13	1.06	0.028	0.062	0.169
d19 Backtransformed	12.6	12.2	11.6	11.7	13.4	11.4	-	-	
d26 (log)	1.20	1.20	1.13	1.20	1.27	1.18	0.038	**0.013**	0.320
d26 Backtransformed	15.9	15.8	13.6	15.7	18.8	15.2	-		
d33 (log)	1.22	1.19	1.17	1.25	1.33	1.27	0.039	0.299	0.155
d33 Backtransformed	16.7	15.5	14.7	17.8	21.3	18.4	-		
d40 (log)	1.30	1.32	1.33	1.34	1.40	1.36	0.044	0.119	0.264
d40 Backtransformed	19.9	21.0	17.2	22.0	25.4	23.1	-		

Table A4.6 Effect of phosphorus (P added vs no P added) at different soil pH levels on seedling shoot height (CNG and Phalaris) during the growing period (No nitrogen treatments).

	Effect of P Fertiliser										**P-Values**	
	pH 1			**pH 2**			**pH 3**			**s.e. of effect (*within pH level*)**		
	No P	P Added	effect	No P	P Added	effect	No P	P Added	effect		pH main effect	Presence of P fertiliser by pH Interaction
Seedling Ht (cm)												
d5 (log)	0.88	0.92	0.04	0.90	0.92	0.02	0.91	0.93	0.02	0.023	0.575	0.858
d5 Backtransformed	7.6	8.3	-	8.0	8.3	-	8.1	8.5	-	-	-	
d12 (log)	0.88	0.97	0.08	0.94	0.98	0.04	0.90	0.98	0.09	0.027	0.315	0.439
d12 Backtransformed	7.6	9.2	-	8.7	9.5	-	7.9	9.6	-	-	-	
d19 (log)	0.96	1.15	0.19	1.04	1.14	0.10	0.95	1.11	0.16	0.028	0.062	0.099
d19 Backtransformed	9.1	14.0	-	10.9	13.8	-	8.9	13.0	-	-	-	
d26 (log)	0.98	1.31	0.33	1.11	1.30	0.20	0.96	1.26	0.30	0.038	**0.013**	**0.045**
d26 Backtransformed	9.6	20.3	-	12.9	20.0	-	9.0	18.1	-	-	-	
d33 (log)	0.99	1.36	0.37	1.12	1.33	0.21	0.98	1.33	0.35	0.039	0.299	**0.016**
d33 Backtransformed	9.8	22.9	-	13.2	21.4	-	9.6	21.5	-	-	-	
d40 (log)	1.07	1.45	0.38	1.20	1.44	0.24	1.06	1.42	0.36	0.044	0.119	0.097
d40 Backtransformed	11.7	27.9	-	15.9	27.8	-	11.5	26.2	-	-	-	

Table A4.7 Effect of species (CNG vs Phalaris) & phosphorus (P added vs no P added) on mature plant shoot weight, leaf area, root weight and root to shoot ratio at harvest (No Nitrogen treatments).

Measurement	**Chilean needle grass**		**Phalaris**		**s.e.d.**			**P-Values**		
	No P added (a)	P added (b)	No P added (a)	P added (b)	(a) vs (b)	(a) vs (a)	(b) vs (b)	Species (average irrespective of P)	P Value for the difference between P added and no P added s)	P Value for the difference between P added and no P added differing with species**
Shoot Wt – Log (x)	0.66	0.79	0.36	0.38	0.045	0.052	0.041	**$1.4 \text{ x } 10^{-13}$**	**0.027**	0.098
Backtransformed (grams)	4.5	6.1	2.3	2.4	-	-	-			
Leaf area – Log(x + 250)	2.65	2.68	2.66	2.64	0.024	0.028	0.020	0.112	0.618	0.129
Backtransformed (cm^2)	193	231	202	184	-	-	-			
Root Wt – Log (x)	1.35	1.39	1.40	1.62	0.100	0.115	0.082	**0.016**	0.074	0.215
Backtransformed (grams)	22.3	24.5	25.1	41.5	-	-	-			
Root:Shoot – Log (x)	0.69	0.61	0.99	1.24	0.096	0.111	0.079	**$3.33 \text{ x} 10^{-9}$**	0.252	**0.020**
Backtransformed	4.9	4.0	9.9	17.4	-	-	-			

Table A4.8 Effect of species (CNG vs Phalaris) & phosphorus (P added vs no P added) on mature plant height during the growing period (No nitrogen treatments).

Measurement	**Chilean needle grass**		**Phalaris**			**s.e.d.**			**P-Values**	
	No P added (a)	P added (b)	No P added (a)	P added (b)	(a) vs (b)	(a) vs (a)	(b) vs (b)	Species (average irrespective of P)	P Value for the difference between P added and no P added s)	P Value for the difference between P added and no P added differing with species**
Average plant Ht (cm)										
d148	71	70	52	54	3.5	4.1	2.9	**2.5 x10^{-8}**	0.685	0.558
d120	55	54	34	32	2.3	2.7	1.9	**3.7 x10^{-15}**	0.361	0.675
d104	57	63	41	39	2.8	3.2	2.3	**8.8 x10^{-13}**	0.298	**0.033**
d96	32	45	38	47	2.7	3.1	2.2	0.122	**2.3 x10^{-8}**	0.293
d89	48	57	41	36	4.0	4.	3.2	**1.4 x10^{-8}**	0.458	**0.015**
d84	46	57	42	42	3.8	4.4	3.1	**0.000010**	0.055	**0.040**
d75	40	55	41	43	3.1	3.6	2.6	**0.00057**	**0.00018**	**0.0063**
d63	27	41	36	46	2.5	2.8	2.0	**0.00028**	**4.1 x10^{-10}**	0.352
d54	23	33	26	42	1.8	2.1	1.5	**7.6 x10^{-8}**	**2.9 x10^{-16}**	**0.016**
d40	16	23	14	30	1.6	1.9	1.3	**0.00014**	**1.0 x10^{-16}**	**0.00026**
d33	14	19	11	26	1.3	1.5	1.1	**0.00016**	**1.5 x10^{-18}**	**2.8 x10^{-6}**
d26	13	17	10	22	1.0	1.3	0.8	**0.00032**	**5.1 x10^{-20}**	**2.1 x10^{-7}**
d19	11	12	9	15	0.7	0.8	0.6	**0.047**	**3.0 x10^{-11}**	**5.2 x10^{-7}**
d12	9	9	8	9	0.4	0.5	0.3	**0.023**	**0.0065**	**0.016**
d5	9	9	8	8	0.3	0.4	0.3	**0.00012**	0.479	0.289

Table A4.9 Effect of species (CNG vs Phalaris) & Soil pH on mature plant shoot weight, leaf area, root weight and root to shoot ratio at harvest (No nitrogen treatments). Note: Species P values are the same as in table 13.

Measurement	**Chilean needle grass**			**Phalaris**			**s.e.d.**	**P-Values**	
	pH 5	pH 7	pH 9	Ph 5	pH 7	pH 9		pH (both species)	Species by pH Interaction
Shoot Wt – Log (x)	0.68	0.77	0.78	0.19	0.43	0.49	0.052	**0.000015**	**0.024**
Backtransformed (grams)	4.8	5.9	6.0	1.6	2.7	3.1	-		
Leaf area – Log(x + 250)	2.64	2.68	2.69	2.59	2.66	2.68	0.028	**0.0030**	0.354
Backtransformed (cm^2)	190	226	237	136	202	238	-		
Root Wt – Log (x)	1.42	1.26	1.45	1.54	1.55	1.54	0.116	0.493	0.430
Backtransformed (grams)	26.4	18.2	28.1	34.8	35.6	35.0	-		
Root:Shoot – Log (x)	0.74	0.49	0.67	1.35	1.12	1.01	0.111	**0.0095**	0.129
Backtransformed	5.5	3.1	4.7	22.3	13.2	10.2	-		

Table A4.10 Effect of species (CNG vs Phalaris) & Soil pH on mature plant height during the growing period (No nitrogen treatments).

Measurement	**Chilean needle grass**			**Phalaris**			**s.e.d.**	**P-Values**	
	pH 5	pH 7	pH 9	PH 5	pH 7	pH 9		pH (both species)	Species by pH Interaction
Average plant Ht (cm)									
d148	67	74	70	45	56	59	4.1	**0.0055**	0.132
d120	53	57	53	30	32	35	2.7	0.203	0.203
d104	60	65	58	37	40	43	3.2	0.223	0.151
d96	46	38	40	39	49	44	3.1	0.659	**0.00047**
d89	53	57	52	35	40	38	4.6	0.378	0.747
d84	52	55	53	37	47	41	4.4	0.148	0.560
d75	53	49	47	38	47	43	3.6	0.498	**0.027**
d63	39	34	35	38	47	42	2.8	0.613	**0.0046**
d54	31	28	29	36	38	35	2.1	0.272	0.230
d40	21	21	20	27	25	23	1.9	0.109	0.479
d33	18	18	16	22	22	19	1.5	0.095	0.731
d26	16	16	14	20	18	16	1.2	**0.0023**	0.637
d19	13	12	11	14	13	12	0.8	**0.0026**	0.551
d12	10	9	9	9	8	9	0.5	**0.0047**	0.153
d5	9	8	9	8	7	8	0.4	**0.0028**	0.311

Table A4.11 Average and combined (CNG and Phalaris) effect of phosphorus (P Added vs No P Added) at different soil pH levels on mature plant heights during the growing period (No nitrogen treatments).

Measurement	**Effect of P Fertiliser**									**s.e. of effect (*within pH level*)**	**P-Values** Presence of P fertiliser by pH Interaction
	pH 5			**pH 7**			**pH 9**				
	No P	P Added	effect	No P	P Added	effect	No P	P Added	Effect		
Average plant Ht (cm)											
d148	58	55	-3	60	67	7	65	65	0	4.3	0.251
d120	43	41	-2	45	44	0	46	43	-3	2.9	0.810
d104	48	49	0	50	54	4	49	51	2	3.4	0.711
d96	37	45	7	36	48	11	31	47	16	3.3	0.176
d89	46	43	-3	44	50	6	43	46	4	4.9	0.354
d84	46	44	-2	45	54	9	41	50	9	4.7	0.158
d75	42	48	6	43	50	7	37	50	13	3.9	0.380
d63	32	42	10	33	44	11	29	44	15	3.0	0.446
d54	26	39	13	25	37	12	23	36	13	2.3	0.977
d40	15	29	14	16	26	10	14	25	11	2.0	0.242
d33	11	24	13	14	23	9	12	21	9	1.6	0.183
d26	11	22	11	13	19	7	11	17	7	1.2	**0.024**
d19	10	15	6	10	13	3	10	12	2	0.8	**0.016**
d12	8	10	2	8	9	1	9	9	0	0.5	**0.010**
d5	8	9	0	8	8	0	9	8	-1	0.4	0.184

“You can’t do it today…

…there’s enough wind to blow a dog off a trailer.”