5.4.2 Toolleen

Chilean needle grass basal cover

All plots had between 10 and 20% basal cover of CNG at the start of the trial (Figure 5.20). Flupropanate reduced the basal cover of CNG to less than 2% ('set flu' and 'other flu,' $P = 2.3 \times 10^{-6}$) during winter 2004, however 'set flu' plots began to have more CNG basal cover than 'other flu' plots, and this difference became significant from autumn 2005 onwards ($P = 0.019$, $P = 0.018$, $P = 0.003$, $P = 0.007$). By the end of the trial 'set flu' had more CNG than any other treatment (30%) whilst 'other flu' had consistently less than 10%.

Desirable perennial desirable grass basal cover

Desirable perennial grass basal cover was most prevalent during the spring periods (reaching a maximum of 25%), although its presence was highly variable between plots for the 2003 and 2004 seasons (Figure 5.21). During the 2005 season, resown plots ('other gly') generally maintained a 5 – 20% cover of desirable perennial grass, whilst all other plots were below 2% cover for most of the year ($P = 1.3 \times 10^{-11}$, $P = 0.0051$, $P = 0.0037$, $P = 3.3 \times 10^{-8}$, $P = 0.0017$) – 'other flu' plots had more than 10% cover during winter 2005 only.

Annual grass basal cover

Annual grass basal cover rose in winter and spring and fell during summer and autumn in all treatments with the lifecycles of these annual grasses (Figure 5.22). While there were no consistent trends from year to year, 'set flu' plots had consistently low cover of annual grasses from winter 2004 onwards ($P = 0.035$), whilst 'set' plots had high annual grass cover during winter 2005 ($P < 0.001$), and together with 'other flu' during spring 2005 ($P < 0.001$).

Broadleaf weed basal cover

Broadleaf weed cover increased during the spring period across all treatments for the first year (1 – 7%) followed by a decrease to less than 2% cover. During the following spring periods, plots that had been sprayed with flupropanate ('set flu' and 'other flu') tended to have more broadleaf weeds (2 – 7% cover) than the other 3 treatment groupings (all less than 2% cover), this became significant in spring 2005 ($P = 0.008$)(Figure 5.23). Within the 'other flu' treatment grouping at this time, lockup plots had significantly less broadleaf weeds than strategically grazed plots ($P = 0.010$).

Vegetative litter basal cover

Vegetative litter basal cover fluctuated for all treatments throughout the seasons dependent on rainfall and seasonal growth, especially for flupropanate plots ('set flu' and 'other flu,' Figure 5.24). Towards the end of the trial vegetative litter cover in 'set flu' plots began to decrease and was significantly less than unsprayed plots by autumn 2005 ('set' and 'other no herb,' $P < 0.001$, $P = 0.006$, $P = 0.003$) any other treatment by summer 2005/06 ($P < 0.001$).

Bare soil basal cover

All treatment groupings tended to have similar amounts of bare soil throughout the experiment (Figure 5.25), However, 'other gly' that had more bare soil after sowing in winter 2003 ($P < 0.001$) and 'set flu' that generally had more bare soil then all the other treatments from spring 2004 onwards ($P < 0.001$, $P = 0.002$, $P = 1.3 \times 10^{-6}$, $P = 0.002$, $P < 0.001$). Within the 'other flu' treatment grouping, strategically grazed plots had significantly more bare soil than lockup grazed plots during autumn 2005 ($P = 0.006$).

Panicle seed harvest and viability

Within flupropanate plots, set stock plots had significantly less standing CNG panicle seed than lockup plots (Table 5.9). Within non flupropanate plots, both set stock and strategic graze plots had significantly less standing CNG panicle seed than lockup plots ($P < 0.001$). Grazing regime or herbicides did not affect the viability of standing CNG panicle seed.

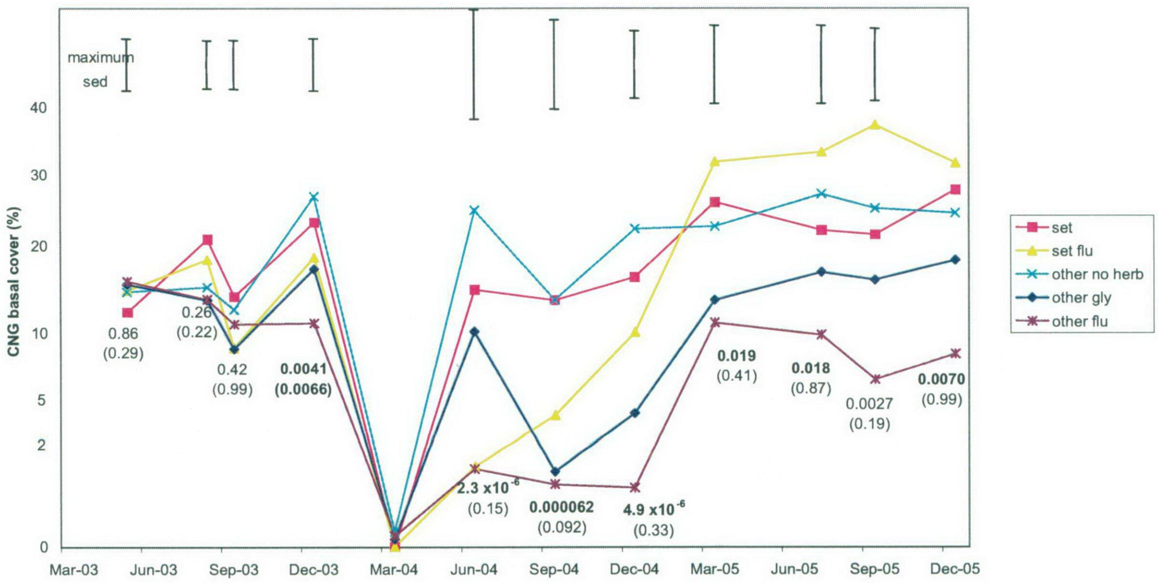

Figure 5.20 Effect of grazing management (Set stocked or other; combined lockup and strategic graze) and herbicide (none, glyphosate and flupropanate) on CNG basal cover in pasture at the Toolleen Best Practice management site. P values presented for between treatment groupings and within treatment groupings (in brackets).

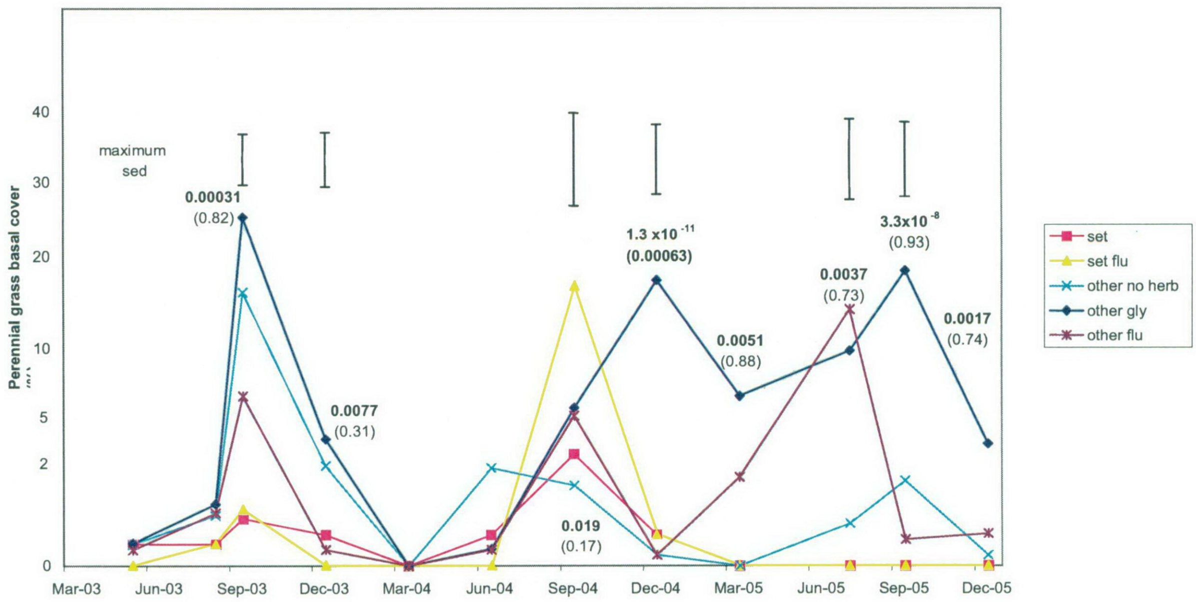

Figure 5.21 Effect of grazing management (Set stocked or other; combined lockup and strategic graze) and herbicide (none, glyphosate and flupropanate) on perennial grass basal cover in pasture at the Toolleen Best Practice management site. P values presented for between treatment groupings and within treatment groupings (in brackets).

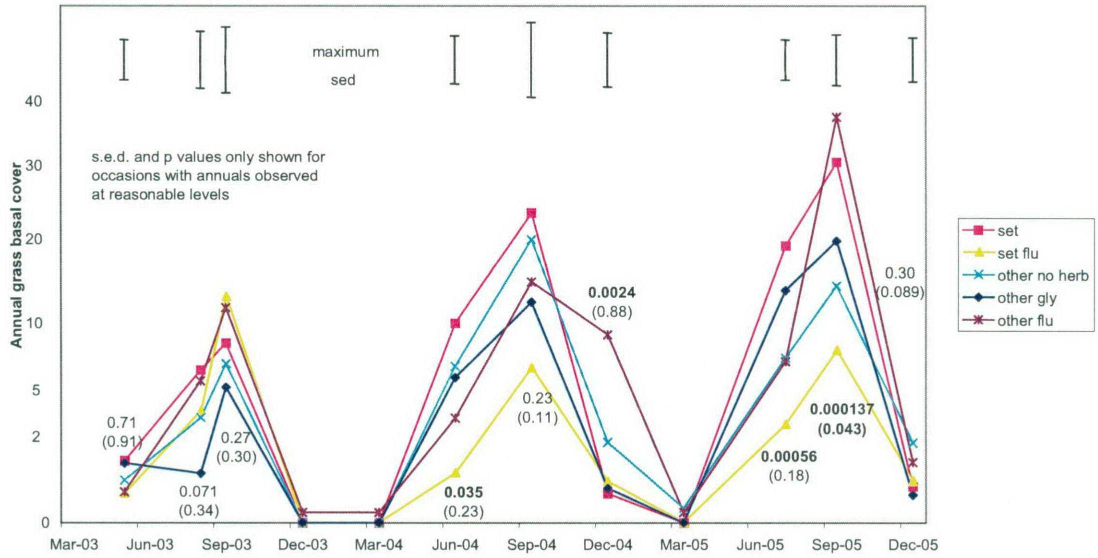

Figure 5.22 Effect of grazing management (Set stocked or other; combined lockup and strategic graze) and herbicide (none, glyphosate and flupropanate) on annual grass basal cover in pasture at the Toolleen Best Practice management site. P values presented for between treatment groupings and within treatment groupings (in brackets).

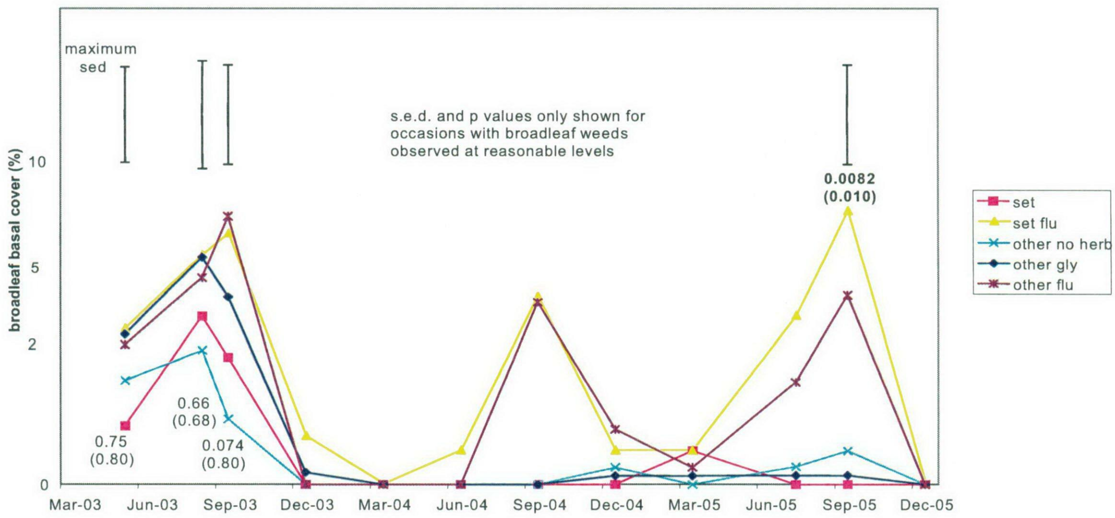

Figure 5.23 Effect of grazing management (Set stocked or other; combined lockup and strategic graze) and herbicide (none, glyphosate and flupropanate) on broadleaf weed basal cover in pasture at the Toolleen Best Practice management site. P values presented for between treatment groupings and within treatment groupings (in brackets).

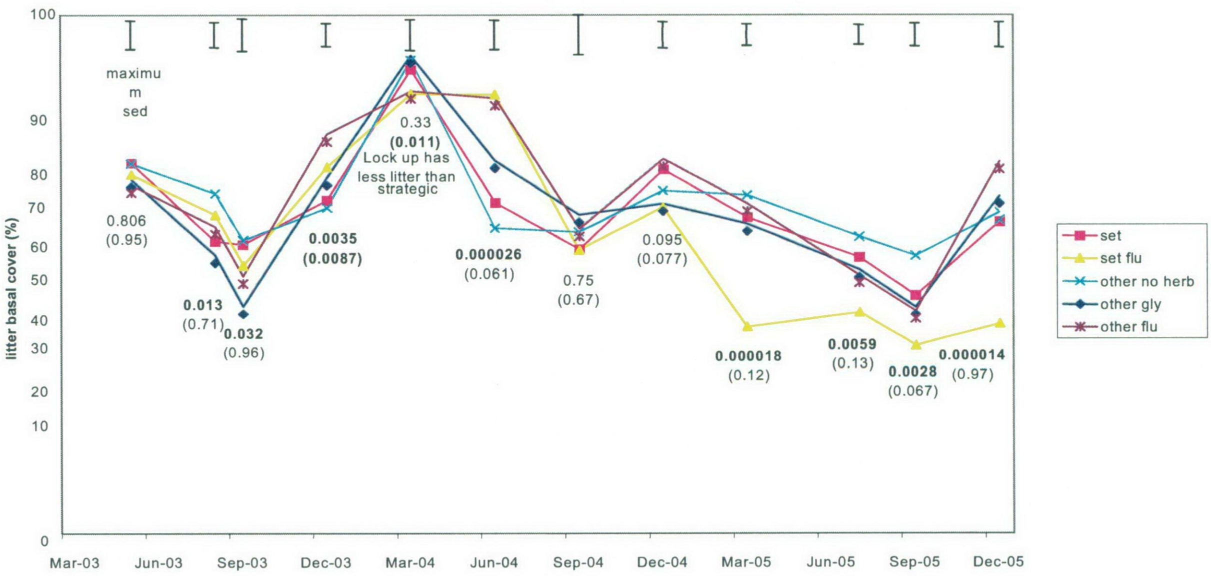

Figure 5.24 Effect of grazing management (Set stocked or other; combined lockup and strategic graze) and herbicide (none, glyphosate and flupropanate) on vegetative litter basal cover in pasture at the Toolleen Best Practice management site. P values presented for between treatment groupings and within treatment groupings (in brackets).

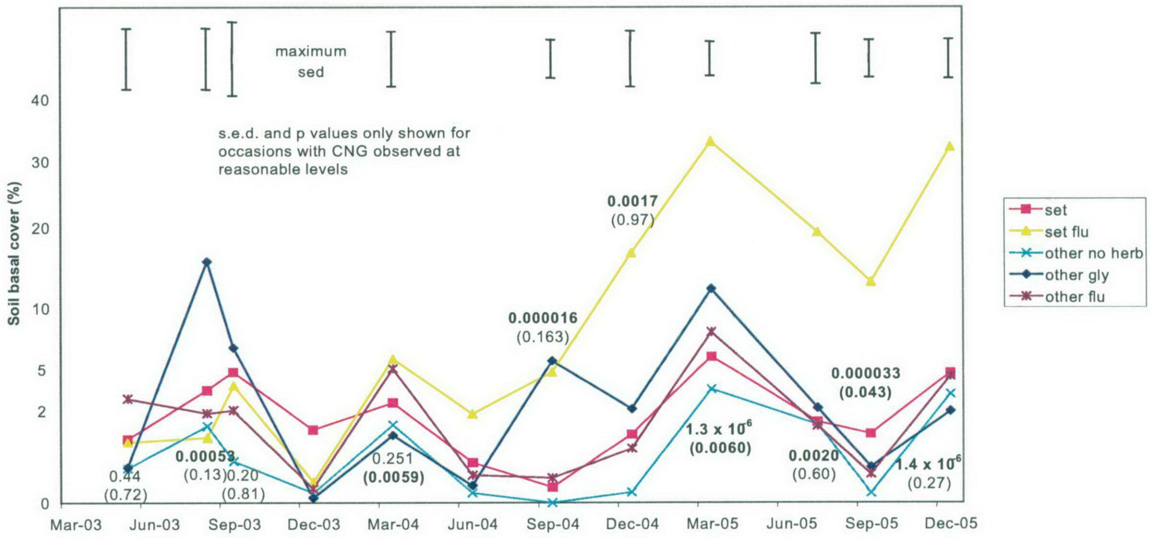

Figure 5.25 Effect of grazing management (Set stocked or other; combined lockup and strategic graze) and herbicide (none, glyphosate and flupropanate) on bare soil basal cover in pasture at the Toolleen Best Practice management site. P values presented for between treatment groupings and within treatment groupings (in brackets).

Table 5.9 - Effect of treatments on panicle seed production and viability at the Toolleen regional best practice management site 2005.

Measurement	Flupropanate			No Flupropanate (including glyphosate/resow and no spray)			s.e.d.			P Value	
	Set Stock^A	Strategic^A	Lockup^A	Set Stock^B	Strategic^B	Lockup^B	A vs A	B vs B	A vs B	Between shown treatment combinations	Within shown treatment combinations
Panicle seed Wt (g/m^2)											
Log (y+1) transformed	0.20	0.54	1.12	1.68	1.67	2.16	0.368	0.212	0.300	**0.000015**	0.842
Backtransformed	0.6	2.5	12.1	47.3	46.0	142.5	-	-	-		
Panicle seed Viability (%)											
Angular transformed	75	82	76	72	77	81	8.7	5.0	7.1	0.775	0.717
Backtransformed	94	98	94	90	95	98	-	-	-		

5.4.3 Goulburn

Chilean needle grass basal cover

All treatment groupings had between 20 – 30% CNG basal cover at the start of the experiment, however during winter 2003 CNG cover began to decrease in plots that had been sprayed with herbicide ('other gly,' 'other flu' and 'set flu,' P = 0.023)(Figure 5.26). This difference became significant in spring 2003 when the 3 sprayed treatment groupings had less than 20% CNG cover compared to over 30% CNG cover in the other 2 groupings (P = 0.000040).

By the end of the experiment, only the 'other gly' treatment grouping had less than 10% CNG basal cover (P < 0.001). Both of the set stock treatments ('set' and 'set flu' had above 40% CNG cover.

Perennial desirable grass basal cover

Plots that had been sprayed with glyphosate and resown generally had more perennial grass basal cover than any other treatment from winter 2003 onwards, this became significant from autumn 2004 (P <0.01)(Figure 5.27). Within 'other gly' plots, strategically grazed plots had significantly more perennial grass basal cover than lockup graze plots from autumn 2004 to summer 2004/05 (P = 0.030, P = 0.050, P = 0.018, P = 0.0037, P = 0.0029).

Annual grass basal cover

Annual grass basal cover rose in winter and spring and fell during summer and autumn in all treatments with the lifecycles of these annual grasses (Figure 5.28). While there were no consistent trends from year to year, the 'other gly' and 'other flu' treatment groupings had significantly high annual grass basal covers (approx. 10% and above) during the spring and winter periods throughout the trial (P = 0.039, P = 0.0014, P = 0.010).

Broadleaf weed basal cover

Broadleaf weed basal cover was not observed at reasonable levels to calculate s.e.d. values and corresponding P values at the data collection occasions (Figure 5.29).

Vegetative litter basal cover

Vegetative litter cover was similar across all the treatment groupings (30-80% cover) and fluctuated with seasonal conditions (Figure 5.30). 'set flu' plots tended to have less vegetative litter than other treatments during 2004.

The 'other gly' treatment grouping had a high period of vegetative litter cover ($P < 0.001$, $P = 0.003$) following glyphosate application in autumn 2005, followed by low vegetative litter cover by late spring ($P = 0.003$). At the end of the experiment, 'other flu' had significantly more vegetative litter basal cover than the set stocked plots (unsprayed and flupropanate sprayed, $P = 0.0029$).

Bare soil basal cover

The amount of bare soil increased in 'Set flu' plots following treatment application – this difference generally became significantly greater ($P = 0.002$, $P = 0.005$, $P = 0.007$, $P < 0.001$)than the amount of bare soil in all non set stock treatment groupings from spring 2003 until autumn 2005. By the end of the trial all treatment groupings had less than 5% bare soil.

Panicle seed harvest and viability

Strategically grazed plots that were sprayed with flupropanate or glyphosate and resown, had significantly less standing CNG panicle seed than all other treatments except lockup glyphosate resown plots ($P < 0.001$)(Table 5.10). CNG panicle seed in strategically grazed glyphosate sprayed and resown plots were significantly less viable than CNG panicle seed in any other treatment plots ($P = 0.012$).

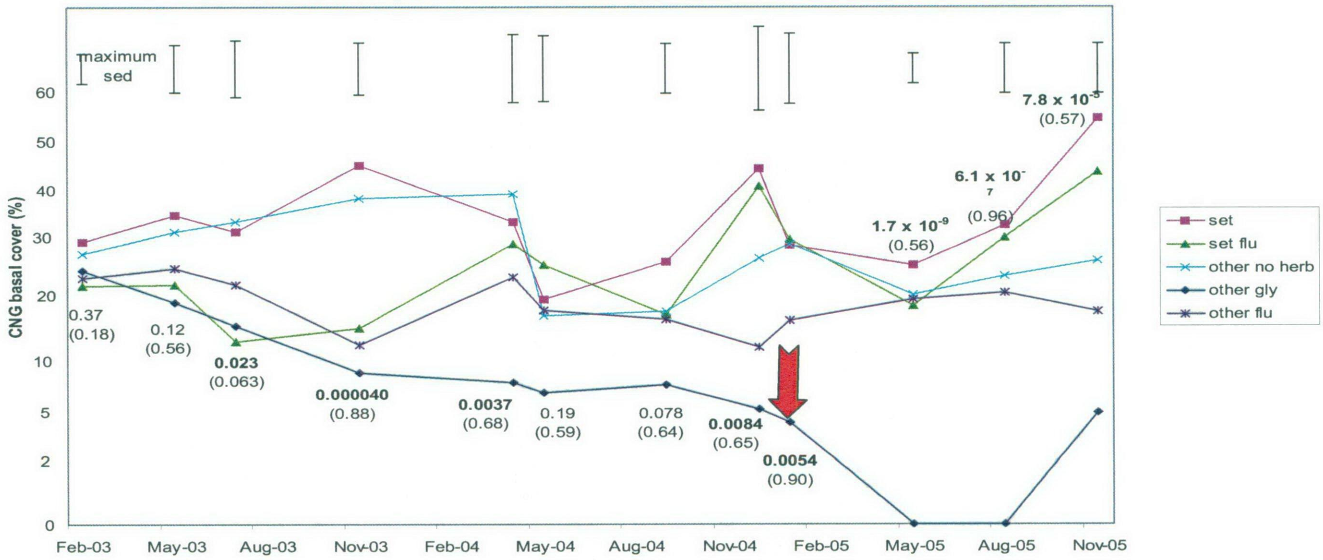

Figure 5.26 Effect of grazing management (Set stocked or other; combined lockup and strategic grazing) and herbicide (none, glyphosate and flupropanate) on CNG basal cover in pasture at the Goulburn best practice management site. Arrow depicts point at which glyphosate was re-applied to 'other gly' (resowing) plots. P values presented for between treatment groupings and within treatment groupings (in brackets).

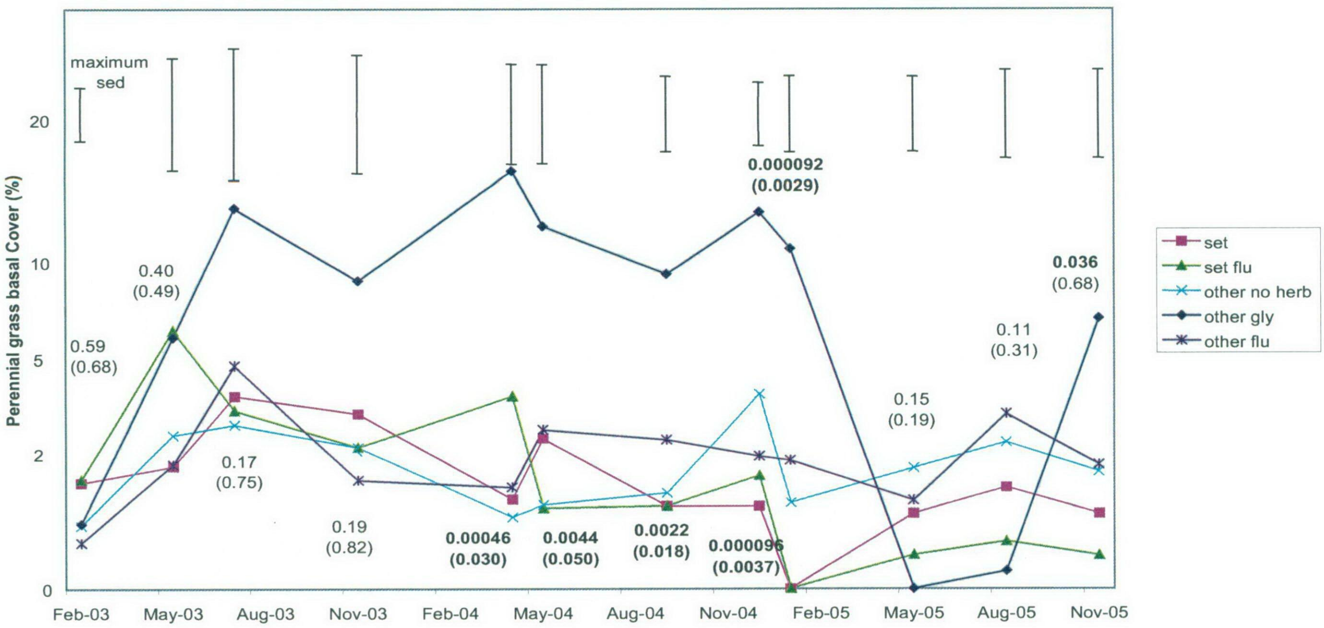

Figure 5.27 Effect of grazing management (Set stocked or other; combined lockup and strategic grazing) and herbicide (none, glyphosate and flupropanate) on perennial grass basal cover in pasture at the Goulburn best practice management site. P values presented for between treatment groupings and within treatment groupings (in brackets).

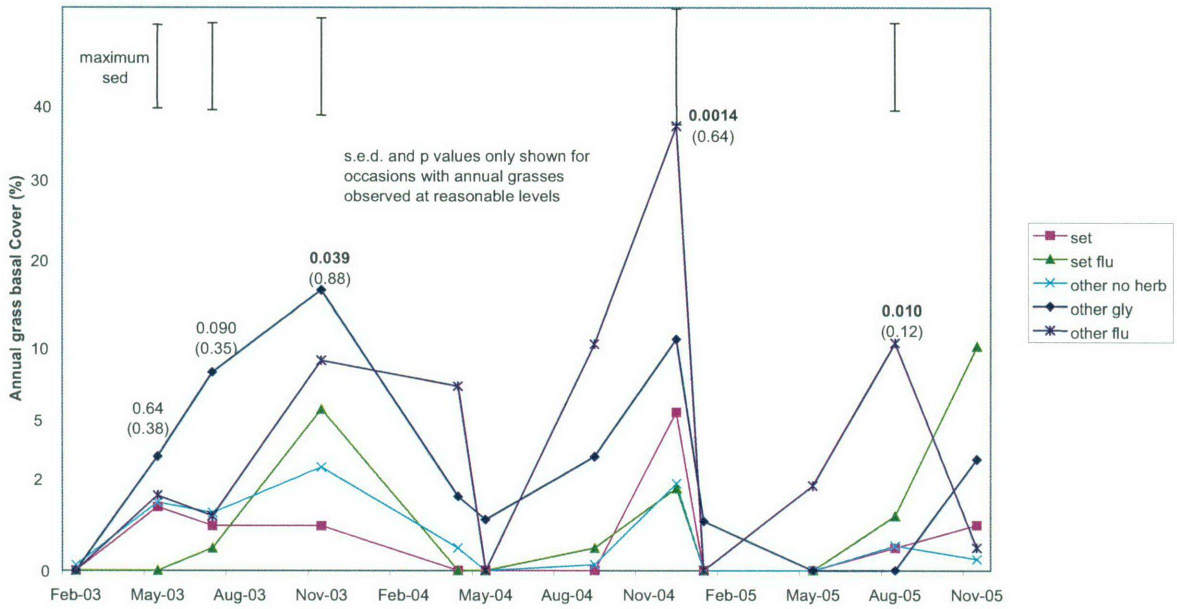

Figure 5.28 Effect of grazing management (Set stocked or other; combined lockup and strategic grazing) and herbicide (none, glyphosate and flupropanate) on annual grass basal cover in pasture at the Goulburn best practice management site. P values presented for between treatment groupings and within treatment groupings (in brackets).

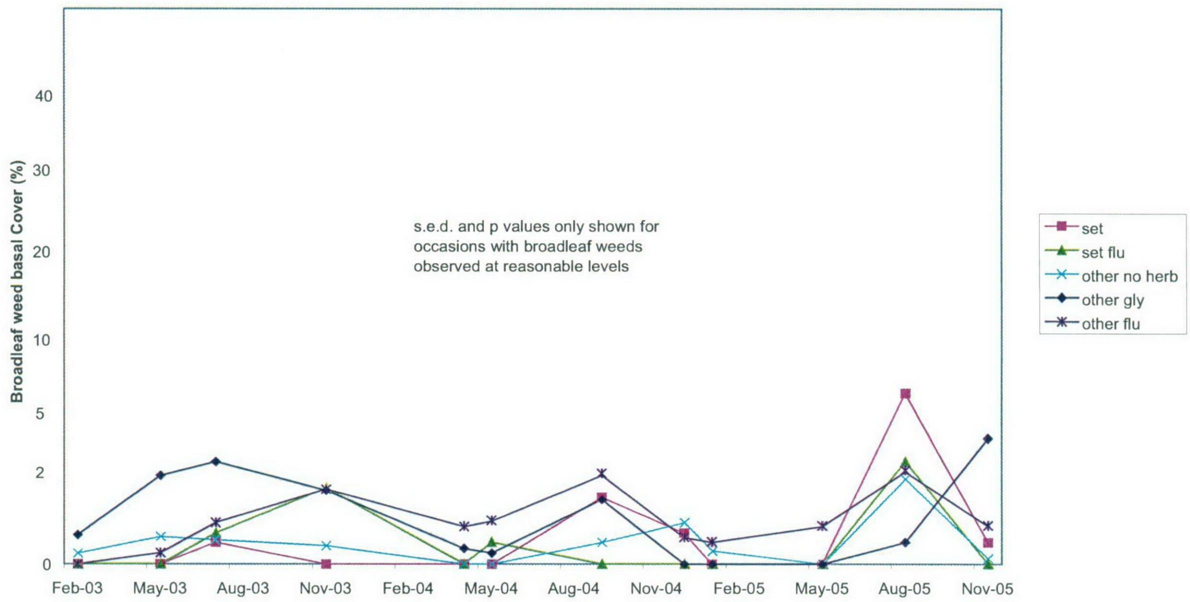

Figure 5.29 Effect of grazing management (Set stocked or other; combined lockup and strategic grazing) and herbicide (none, glyphosate and flupropanate) on broadleaf weed basal cover in pasture at the Goulburn best practice management site. P values presented for between treatment groupings and within treatment groupings (in brackets).

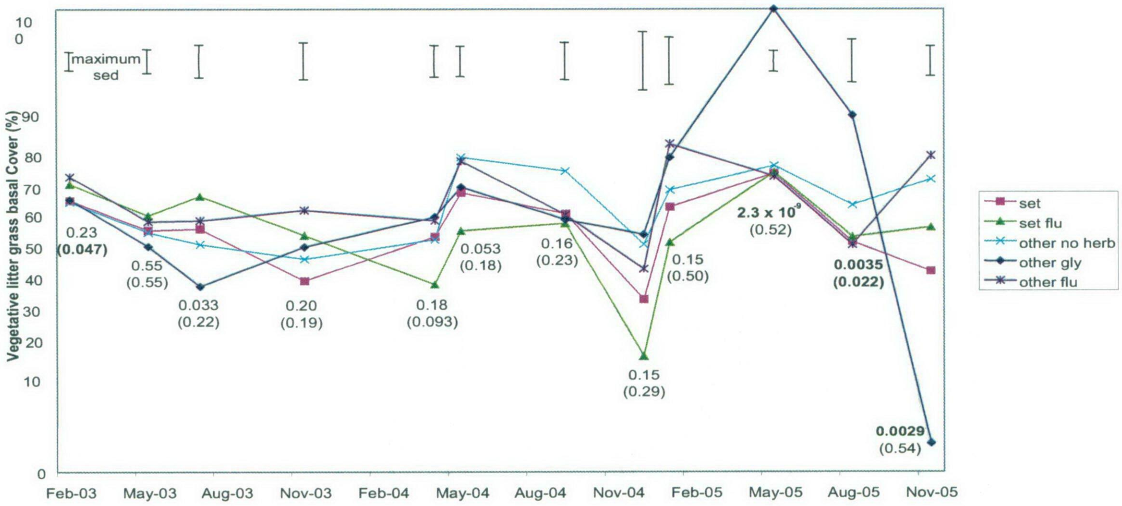

Figure 5.30 Effect of grazing management (Set stocked or other; combined lockup and strategic grazing) and herbicide (none, glyphosate and flupropanate) on vegetative litter basal cover in pasture at the Goulburn best practice management site. P values presented for between treatment groupings and within treatment groupings (in brackets).

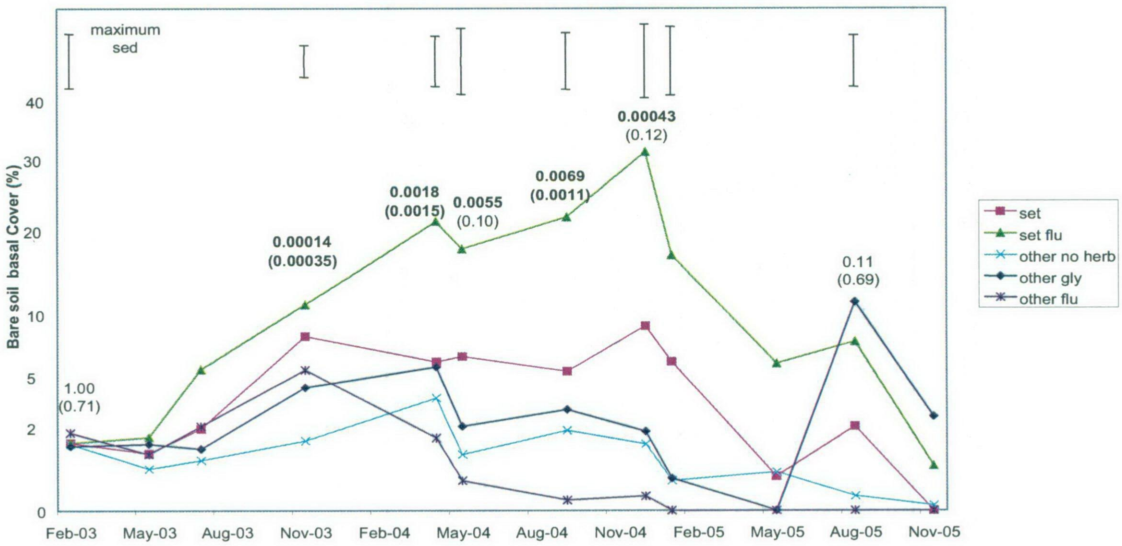

Figure 5.31 Effect of grazing management (Set stocked or other; combined lockup and strategic grazing) and herbicide (none, glyphosate and flupropanate) on bare soil occurrence in pasture at the Goulburn best practice management site. P values presented for between treatment groupings and within treatment groupings (in brackets).

Table 5.10 Effect of treatments on panicle seed production and viability at Goulburn CNG regional best practice site 2005

Measurement	Flupropanate			Glypho-sate		No Spray			s.e.d.			P Value	
	Set Stock^A	Strategic^A	Lockup^A	Strategic^A	Lockup^A	Set Stock^A	Strategic^B	Lockup^B	A vs A	B vs B	A vs B	Between shown treatment combinations	Within shown treatment combinations
Panicle seed Wt (g/m2)													
Log transformed	2.00	0.93	1.86	1.03	1.33	1.60	1.56	2.04	0.226	0.160	0.196	**0.00063**	0.557
Backtransformed	99	8	72	11	21	39	36	110	-	-	-		
Panicle seed Viability (%)													
Angular transformed	82	57	78	38	63	70	68	68	9.4	6.7	8.2	**0.012**	0.254
Backtransformed	98	71	96	37	80	88	86	86	-	-	-		

5.4.4 Glen Innes

Results for Glen Innes are based on a different treatment structure to that used at the other sites. This has been reflected in the treatment groupings that have been used in the statistical analysis for this site.

Chilean needle grass basal cover

CNG cover in the 'gly' plots was less than 5% while all other treatment groups had greater than 10% CNG cover (Figure 5.32). Four of the treatment groupings had less CNG (generally less than 5%) cover by winter 2004 whereas the control plots had an increased CNG cover (15-20%) that remained high until the end of the experiment. Of the four plots that had low CNG cover 'Pasture' and 'gly' treatment groupings increased from spring 2004 and remained at about 10% cover until the end of the experiment.

Desirable perennial grass basal cover

All of the treatment groupings had above 40% desirable perennial grass cover at the start of the experiment (Figure 5.33). Throughout the trial, pasture plots had low perennial grass cover (less than 2%) during autumn 2004 after glyphosate application ($P = 0.0012$), while 'flupropanate' plots generally had high perennial grass cover (at least 20%) from autumn 2005 onwards ($P = 0.001$, $P = 0.003$, $P < 0.001$), whereas all other treatments at the end the experiment had less than 5% cover.

Annual grass basal cover

Annual grass basal cover rose in winter and spring and fell during summer and autumn in all treatments with the lifecycles of these annual grasses (Figure 5.34). Four of the five treatments maintained a relatively steady annual grass cover (less than 7%), whilst 'spraytop' treatments had significant amounts of annual grass cover over the summers of 2003/04, 2004/05 and 2005/06 ($P = 0.004$, $P < 0.001$, $P = 0.008$).

Broadleaf weed *basal cover*

All treatments had less than 5% broadleaf weed cover at the start of the trial. By autumn 2004 'flu' treatment had increased broadleaf weed cover to greater than 5% whereas all other treatments had less than 2% cover (both $P < 0.001$)(Figure 5.35). By the end of the trial, 'flu' plots had significantly more broadleaf weed basal cover than all plots except the 'gly' plots. At the same time, 'gly' plots had significantly more broadleaf weed basal cover than 'spraytop' plots and 'control' plots ($P = 0.01$).

Vegetative litter basal cover

Vegetative litter cover for all treatments was below 2% at the start of the trial and increased to above 20% by spring 2003. During autumn 2004 vegetative litter cover decreased significantly and generally remained low in 'flu' plots to the end of the trial ($P = 0.012$, $P = 0.019$, $P = 0.024$, $P = 0.01$, $P = 0.01$, $P < 0.001$, $P = 0.002$)(Figure 5.36). Throughout the experiment all other treatment groups followed similar seasonal patterns (30-60%), except for 'pasture' and 'gly' during winter 2004 that had high vegetative litter cover (above 70%).

Bare soil basal cover

Bare soil was between 20-30% for all treatments at the start of the trial although this decreased for the 'gly,' 'control' and 'pasture' treatments to less than 5% by autumn 2004 (Figure 5.37. Over the experiment, 'flu' and 'spraytop' generally had 20% bare soil, whereas 'gly,' 'control' and 'pasture' all gained bare soil (5-20%) with the 'control' treatment remaining under 10% bare soil.

Panicle seed harvest and viability

Spraytop plots (set stock and strategic) had significantly less standing CNG panicle seed than any other treatment plot ($P < 0.001$)(Table 5.11). Within the glyphosate plots, strategic graze plots had significantly less standing CNG panicle seed than set stock plots. Within the no spray plots, strategic graze plots had significantly less standing CNG panicle seed than set stock plots. Panicle seed from spraytop set stock plots had significantly less viability than panicle seed from other treatment plots ($P < 0.001$). Panicle seed from no spray strategic graze plots had significantly less viability than panicle seed from no spray set stock treatment plots ($P < 0.001$).

Note – viability could not be calculated for spraytop strategic graze as no panicle seeds were harvested

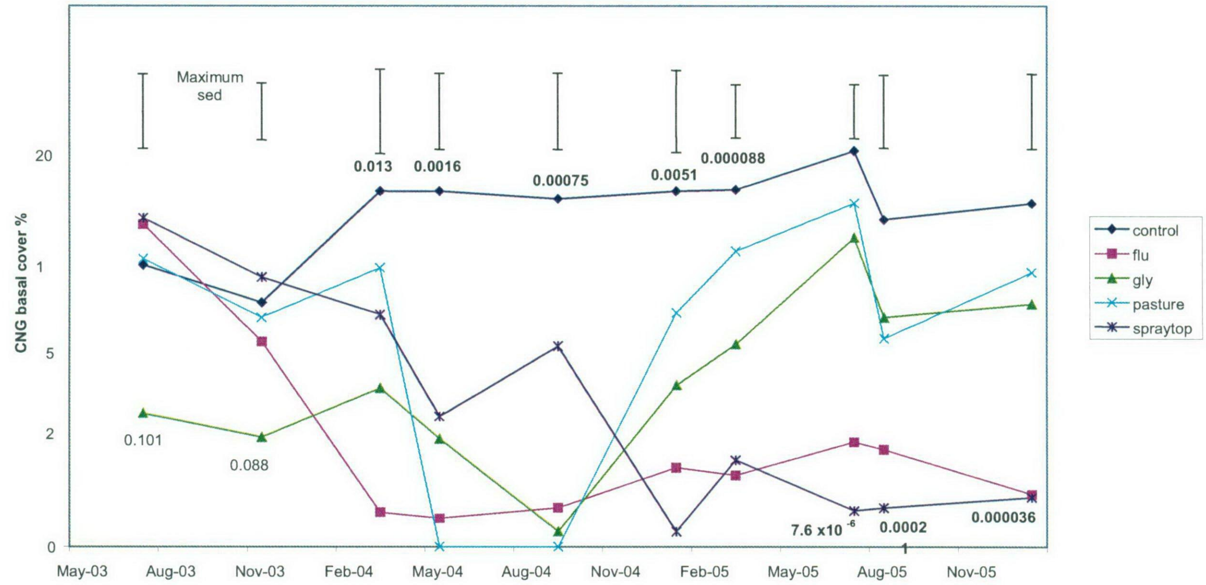

Figure 5.32 Effect of management (unsprayed control, flupropanate spray, glyphosate spray, pasture resowing or glyphosate spraytop) on CNG basal cover in pasture at the Glen Innes best practice management site. P values presented for between treatment groupings and within treatment groupings (in brackets).

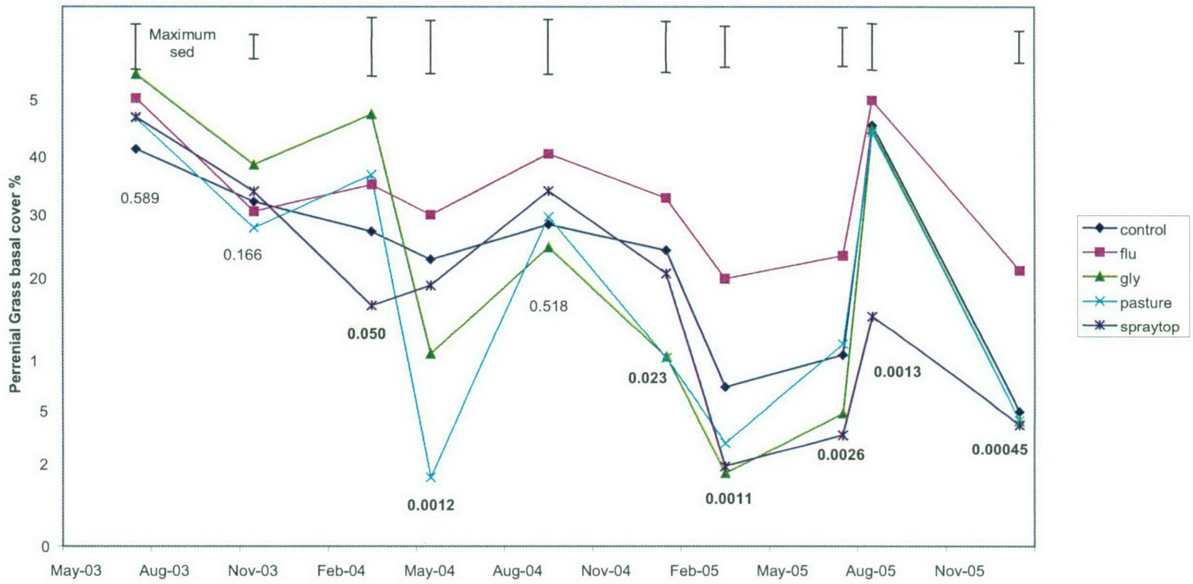

Figure 5.33 Effect of management (unsprayed control, flupropanate spray, glyphosate spray, pasture resowing or glyphosate spraytop) on perennial grass basal cover in pasture at the Glen Innes best practice management site. P values presented for between treatment groupings and within treatment groupings (in brackets).

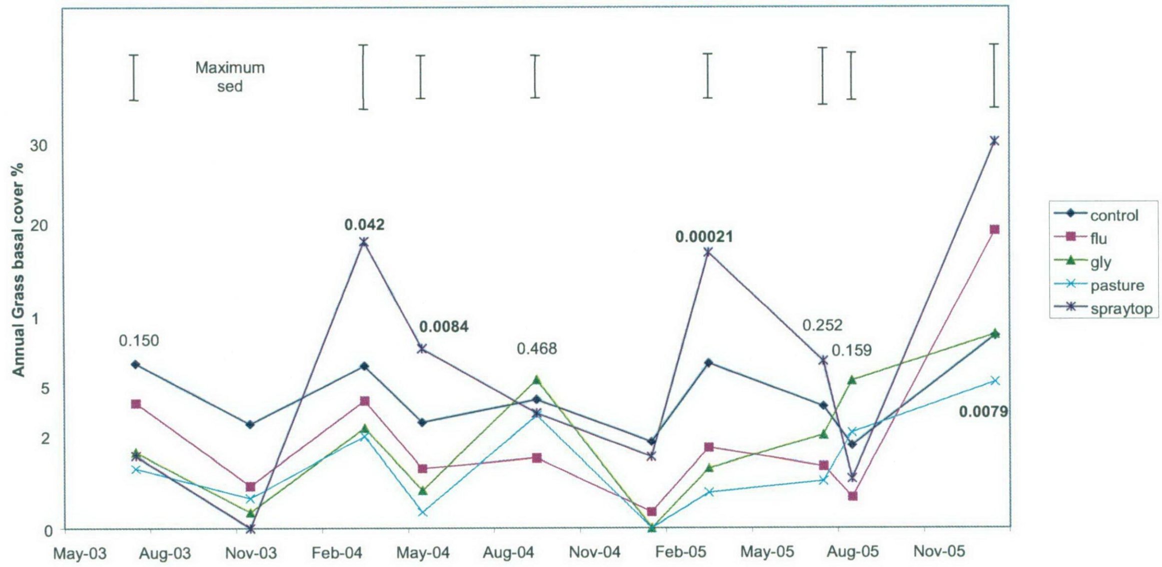

Figure 5.34 Effect of management (unsprayed control, flupropanate spray, glyphosate spray, pasture resowing or glyphosate spraytop) on annual grass basal cover in pasture at the Glen Innes best practice management site. P values presented for between treatment groupings and within treatment groupings (in brackets).

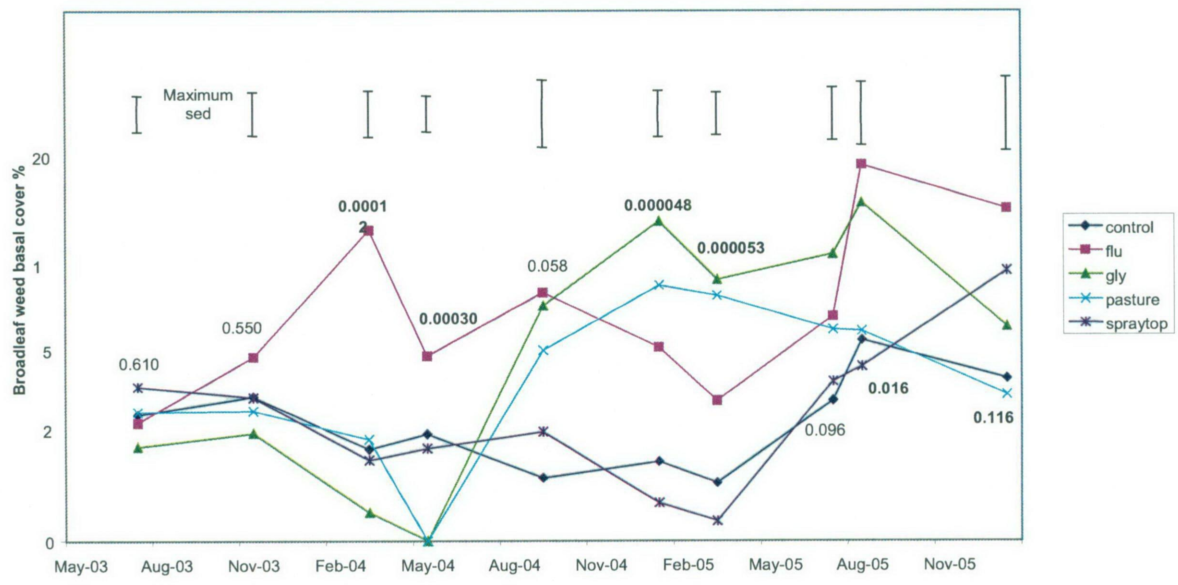

Figure 5.35 Effect of management (unsprayed control, flupropanate spray, glyphosate spray, pasture resowing or glyphosate spraytop) on broadleaf weed basal cover in pasture at the Glen Innes best practice management site. P values presented for between treatment groupings and within treatment groupings (in brackets).

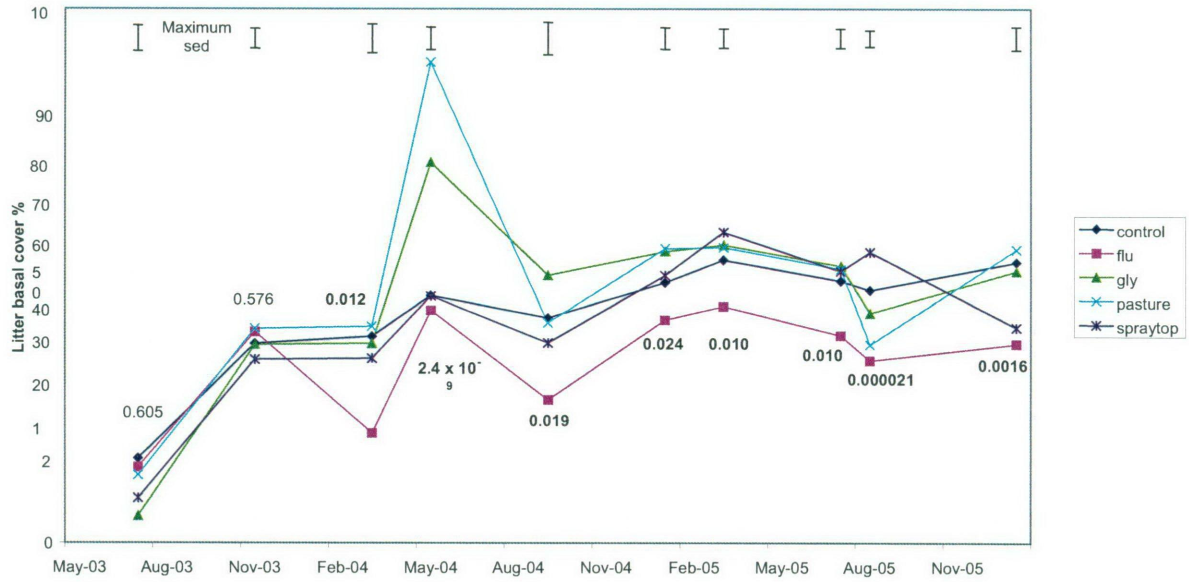

Figure 5.36 Effect of management (unsprayed control, flupropanate spray, glyphosate spray, pasture resowing or glyphosate spraytop) on vegetative litter basal cover in pasture at the Glen Innes best practice management site. P values presented for between treatment groupings and within treatment groupings (in brackets).

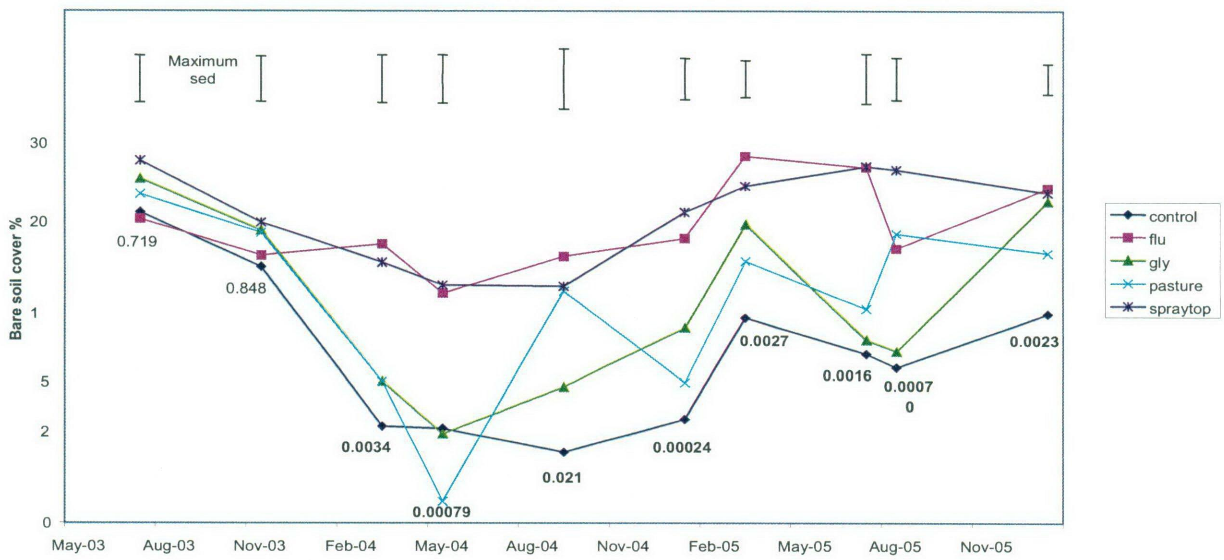

Figure 5.37 Effect of management (unsprayed control, flupropanate spray, glyphosate spray, pasture resowing or glyphosate spraytop) on bare soil occurrence in pasture at the Glen Innes best practice management site. P values presented for between treatment groupings and within treatment groupings (in brackets).

Table 5.11 Effect of treatments on panicle seed production and viability at Glen Innes regional best practice site 2005

Measurement	Flupropanate		Spraytop		Glyphosate		No Spray		s.e.d.			P Value	
	Set Stock^A	Strategic^A	Set Stock^A	Strategic^A	Set Stock^A	Strategic^A	Set Stock^B	Strategic^B	A vs A	B vs B	A vs B	Between shown treatment combinations	Within shown treatment combinations
Panicle seed Wt (g/m^2)													
Log (y+1) transformed	0.68	0.74	0.16	0.00	1.21	0.87	1.23	0.90	0.237	0.168	0.206	**0.00015**	0.714
Backtransformed	3.8	4.5	0.4	0.0	15.3	6.3	15.8	6.9	-	-	-		
Panicle seed Viability (%)													
Glen Innes Angular transformed	73	78	30	-	71	75	81	70	7.3	5.2	6.3	**0.000084**	0.745
Backtransformed	91	96	26	-	90	93	97	89	-	-	-		

5.5 Discussion

At the start of these trials, the current four trial sites represented the known range of CNG and were strategically chosen to represent the range of climatic conditions in which CNG is found. Apart from the regional weather pattern differences between the sites, the experiments were set up and managed in a similar manner to one another using common treatments to correlate the effect of management on the response of CNG. Each site was grazed by sheep at district stock rates dependant on the seasonal conditions of the region. District rainfall patterns appear to have influenced effectiveness of management strategies. This aspect is discussed further below.

5.5.1 Effects of grazing management on pasture basal composition

The effect of set stock grazing on pasture composition was generally consistent with findings from other grazing experiments and known plant competition theories (Campbell 1997b; DNRE 2002; Dowling *et al.* 2000; DPI 2000; NSW-Agriculture 1998; Taylor and Sindel 2000; Tilman; Warn 1995). Set stock grazing is known to lead to selective grazing and continued grazing of more palatable species in the pasture sward, depleting the plants' carbohydrate reserves and often leading to their decline in the population leading to the occurrence of bare ground (DNRE 2002; DPI 2000).

Set stock grazing reduced the desirable perennial grass basal cover leading to less ground cover, especially at the Greenvale and Goulburn sites. This reduction in ground cover decreased competition for soil resources by desirable species leading to an increase or reinvasion of CNG basal cover at most sites.

Strategic grazing uses higher stock rates to reduce selective grazing in a managed system such that all pasture species are grazed evenly and sufficient pasture mass is left ungrazed to maintain ground cover and enable pasture regeneration (Bedggood 2000; DNRE 2002; DPI 2000; Friend and Kemp 2000; NSW-Agriculture 1998; Popay and Field 1996). When the strategic grazing theory was applied to plots of CNG it was generally successful across the sites with strategically grazed plots having less standing CNG panicle seed produced than set stock or ungrazed plots, although the correct timing of grazing is crucial for success. Plots that were strategically grazed generally had a more favourable pasture composition with more perennial species and bare soil, annual grasses and broadleaf weeds.

Over the experimental period it was observed that sheep were reluctant to graze CNG stems once the panicle had emerged even at stock rates as high as 300 DSE/ha. Another observation made during this study that places some limitations on strategic grazing is that CNG plants can generate another reproductive tiller within 2 weeks after grazing has concluded. This observation has implications on the ability of strategic grazing to be used in a whole farm context for reducing standing CNG panicle seed. Given that CNG was observed to grow another reproductive tiller within 2 weeks, and a simple rotational grazing system (one week in/ 3 weeks out) requires a four week turnaround, it can be concluded that strategic grazing can only be useful if the entire CNG infestation area represents 25% or less of the rotational area. It is extremely difficult to prevent extensive CNG infestations seeding through grazing management alone.

5.5.2 Effects of chemical control on Chilean needle grass basal composition

Current chemical control options for CNG range from glyphosate which is a non selective, non residual, fast acting (1-2 weeks) knockdown herbicide (under State specific permits) to flupropanate which has some selectivity (*Phalaris aquatica* and *Themeda triandra* (Badgery 2003) show some tolerance), has residual effects (2-3 years) and is slow acting (3-12 months)(APVMA 2005; Nufarm 2005; Taskforce 2006). The use of both of these active constituents resulted in a reduced basal cover of CNG plants at all sites. However, the expected residual action of flupropanate was not observed and is discussed further below.

Flupropanate and interaction with rainfall

Flupropanate applications at 1117.5g a.i./ha reduced CNG basal cover, irrespective of grazing treatment. Similarly, other work has shown that flupropanate at rates from 745g a.i./ha to 2235g a.i./ha can give high levels of CNG control (Duncan 1993; Gaur *et al.*

2005; Storrie and Gardener 1998; Williams 2005). The selectiveness of flupropanate and damage to off target species has been previously questioned (Badgery 2003) and its results/effects considered to be variable in different soil types, even though the active constituent is registered as a selective chemical (Campbell 1997a; Taskforce 2006). The current trial showed that flupropanate resulted in off target damage to *Phalaris aquatica* and *Lolium perenne*. This damage did not occur at Glen Innes, although it became apparent that followup management of flupropanate plots had a large impact on the off target damage and the soil residual activity, that ultimately impacts on the composition of the resulting pasture sward (i.e. Greenvale).

Plots that were sprayed with flupropanate and continually grazed (after the 4 month withholding period) had reduced groundcover, due to decreased competition caused by CNG mortality and grazing pressure on beneficial perennial grasses. This resulted in seasonal fluxes of annual broadleaf and grass weeds. This finding is in agreement with other pasture weed theory related to bare ground and continual grazing (Dowling *et al.* 2000; DPI 2000; Friend and Kemp 2000). Given the high amounts of bare soil in the set stock plots, it is likely that this flupropanate was lost from the soil profile thus allowing CNG regeneration (Taskforce 2006). This regrowth of CNG, attributed to the loss of flupropanate, was observed at all the winter rainfall sites (Goulburn, Toolleen and Greenvale) but not at Glen Innes. Observations of ground cover and weather events that led to these results are discussed below.

For the Greenvale site, the regeneration of CNG may have resulted from an unseasonally large summer rain event that occurred in February 2005 (200 mm rain**, Figure 5.5)** in which significant surface runoff occurred. Given that set stock flupropanate treatments tended to have more bare soil with significantly less vegetative litter than unsprayed set stock plots at the time, it is likely that these flupropanate was washed away, as part of soil loss and disturbance, allowing seedling regeneration (Campbell 1997a). Any residual flupropanate may also have been leached from the soil profile during this rain event due to the plots having a low vegetative litter content to absorb any precipitation.

For the Goulburn site, the increase in CNG basal cover within flupropanate plots may be attributed to regeneration of mature CNG tussocks post spraying, caused by an insufficient application rate or inadequate rainfall after spraying to wash the herbicide into the root zone. Spraying resulted in only a temporary 'brown out' of CNG plants whereas flupropanate is registered to kill CNG at rates as low as 1117.5 g a.i./ha. Flupropanate has been known to provide residual control of other *Nassella* seedlings for 3 –5 years post spraying (Taskforce 2006).

Glyphosate

In these trials, glyphosate was used both as a knockdown herbicide as part of an integrated management strategy to replace CNG with a competitive pasture species across all sites and for spraytopping at low rates to reduce CNG seed set at Glen Innes.

Glyphosate is known to be a non selective/knockdown, non residual herbicide and has the ability to kill many perennial pasture species including *Nassella* grasses (Bourdot and Hurrell 1987; Campbell 1995a; b; Lowien 2002; Nufarm 2005; Pritchard 2003; 2004; Slay 2001; 2002a; b; Stapleton 1995; Storrie and Gardener 1998; Taylor and Sindel 2000). As expected, glyphosate successfully killed CNG tussocks at all sites although the decline in CNG basal cover was shortlived as glyphosate does not have significant residual effect (Nufarm 2005). Areas that were sprayed out by glyphosate were often quickly re-invaded by CNG or other broadleaf weeds, irrespective of resown pasture competition.

Spraytopping using glyphosate is commonly used to delay the loss of feed value and reduce seed set of undesirable annual grass species when sprayed at the seedhead stage (Gatford *et al.* 1999; Siever-Kelly *et al.* 1999). Reducing the seed input reduces the seedbank of these species that may reduce their impact the following season. It has also been used successfully to reduce flowering in a perennial stoloniferous grass, *Agrostis castellana* (bent grass), making it more available for stock over summer (Hill *et al.* 1996). Although glyphosate is a non selective herbicide (Nufarm 2005), and spraytopping is a tool intended to reduce seed set of annual grass species (Pratley 2003; Stapleton 1995), it can also be used to reduce seed production of *Nassella* species and affect pasture composition (Campbell 2001; Gaur *et al.* 2005; Lowien *et al.* 2001; Pritchard 2004). At Glen Innes, spraytopping was a successful management tool as it reduced the seed set of CNG without affecting the long term basal cover of perennial desirable species.

5.5.3 Effect of pasture sowing on pasture basal composition

Pasture resowing treatments were intended to provide a source of competition for CNG for light, and soil resources, and to resist weed invasion (Campbell 1997b; Friend and Kemp 2000; Jackson and Caldwell 1992; Moretto and Distel 1997). Although CNG plants were able to be killed by using glyphosate prior to resowing, unseasonally dry conditions limited pasture seed germination, establishment and vigour during the experimental period. At Greenvale, Toolleen and Goulburn, pastures were resown twice due to poor pasture seed emergence.

The application of glyphosate increased the amount of bare ground and quite often led to broadleaf weed or CNG re-invasion. The resown pasture was less competitive than expected. Desirable perennial grass basal cover was increased by resowing at most sites although it did not reduce the CNG basal cover by means of competition.

5.5.4 Effect of rainfall and temperature patterns on seed set during 2005

Over the experimental period, there was a clear distinction between the Glen Innes (summer rainfall) site and the other winter rainfall sites (Greenvale, Toolleen, Goulburn). Apart from a large unexpected rainfall event at Greenvale during February 2005, Glen Innes was the only site to receive, substantial summer rainfall. Mean monthly temperature generally followed a similar trend across all the trial sites. Greenvale had the least amount of monthly fluctuation between winter and summer possibly owing to its proximity to the coast.

The amount of CNG panicle seed set (measured by seed harvest during December 2005) was generally comparable across all the sites, although more seed was harvested from the winter rainfall sites (Set stock no spray 9.6 – 47 g/m^2) than at the Glen Innes site (Set stock no spray 15.8 g/m^2). This may be due to the harvest occurring towards the end of the seeding period at Glen Innes, when some panicle seeds may have been lost from the seedhead.

5.5.5 Future CNG management research

Chemical control

Chemical control offers a quick reduction of CNG basal cover, although the long term effect of flupropanate on CNG infestations needs to be better understood at all the sites. The significant changes in pasture composition and CNG re-infestation only took effect within the final season of the experimental period. Given that the residual effect of this herbicide seems to be different in the various climatic regions and soil types, a specific recommendation for the use of flupropanate for CNG in different soil types would be helpful. The interaction between grazing management, off target species and flupropanate application needs to be monitored to better understand CNG control in a long term and whole-of-farm context.

Cultural control

Grazing can only be effective in reducing seed set if the grazing is able to reduce the pasture mass of the infestation prior to seedhead emergence. Given the practical difficulty in achieving this reduction on most farms, alternative control techniques need to be investigated for non grazing and non arable areas in order to limit seed production and risk of spread. For non arable areas the effects of fire, on a large plot/paddock scale, have not yet been determined. For non grazing areas, such as roadsides, slashing prior to seedhead production may be a useful tool to reduce the likelihood of CNG spread whilst minimising seed input in to the soil seedbank

Competition against re-infestation

Seasonal conditions during most of the trial period limited pasture growth and competition in resown pasture plots. Pasture species selection for use in resowing CNG infested land, and the use of cropping therefore remains a critical knowledge gap, given the lack of success in establishing competitive pastures at the trial sites. Alternative pasture grasses, soil type interaction with soil fertility, cropping systems and sowing regimes need to be evaluated in the context of whole farm management to maintain agricultural production.

Grazing systems

The use of sheep to graze CNG coming into the reproductive period presents an opportunity to reduce seed input in to the seedbank. Given the risk associated with CNG seed contaminating fleece and being spread, experiments into the use of cattle and alternative grazers is urgently required.

5.6 Conclusion

CNG management techniques had some comparable effects in the winter rainfall zones as opposed to the summer rainfall zone, although rainfall patterns did influence CNG management.

5.6.1 Grazing

Strategic grazing of CNG infestations during seed production reduced the amount of standing CNG panicle seed at all sites. Sheep were averse to grazing reproductive CNG stems (post seed head emergence), as such this technique is only suitable to infestations where CNG represents less than 25% of the grazing rotation area. Continuous grazing, as in the set stock treatments, caused a shift in pasture composition away from desirable perennial species towards a pasture with low soil cover, and intermittent bursts of annual broadleaf and grass weeds, and high levels (up to 40% basal cover) of CNG.

5.6.2 Flupropanate

Although application of flupropanate was able to reduce the basal cover of CNG, with minimal effect on desirable species, the death of CNG resulted in bare ground and increased emergence of broadleaf weeds. This effect was more evident in continuously grazed plots. If the desirable perennial grasses can be further encouraged then such broadleaf weeds are likely to be less important in later seasons

The residual activity of flupropanate was short lived in the winter rainfall sites, especially in set stock plots that had low soil cover and low vegetative litter contents where CNG re-invaded within 2 years of application. In the summer rainfall zone, flupropanate selectively killed CNG and maintained a residual effect for the experimental period, without effecting desirable perennial species. An interaction between soil type and rainfall patterns and districts, may be affecting the residual activity of flupropanate in the soil profile. Flupropanate plots at Glen Innes had low soil cover and vegetative litter levels with isolated periods of broadleaf weed cover Overall, flupropanate significantly reduced CNG panicle seed production.

5.6.3 Glyphosate and resowing

Resowing of pasture species after glyphosate application significantly increased the perennial component of the pasture sward. The low level of pasture competition at Greenvale and Toolleen, and the non residual effect of glyphosate allowed CNG to reinvade to levels of unsprayed plots by summer 2005/06 – yet this was a lower CNG cover than in set stock flupropanate plots. At Goulburn, pasture resown plots, after spraying glyphosate, had reduced CNG basal cover that remained low post sowing. Resown plots often had significantly more perennial grass basal cover than all other treatment plots at Goulburn, whereas at Glen Innes, the success of pasture resowing in reducing CNG basal cover was limited to the effect of glyphosate at sowing, as CNG quickly re-established together with broadleaf weeds.

5.6.4 Spraytopping

Spraytopping can be used to reduce CNG panicle seed production and viability, whilst also reducing the CNG basal cover with minimal effect on desirable perennial species. Bare ground created by spraytopping can lead to an increase in annual grasses.