Managing *Pilosella officinarum* (*Hieracium)* with sulphur in South Island High Country

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Abstract

This work examines the effect of sulphur fertiliser on the presence of *Pilosella officinarum* (mouse-ear hawkweed) in sunny facing tussock grassland at 'Mt. Thomas' in the Lindis Pass, Otago. In a 1992-2006 study the presence or absence of mouse eared hawkweed was assessed by grid sampling of pasture where half the area was top-dressed with 56 kgS/ha every three years. In the top-dressed area mouse-ear hawkweed cover gradually reduced over time when pasture was mown, although there was a slight increase in mouse-ear hawkweed in the year prior to retop-dressing. Summer grazing from 2002 coincided with a further reduction in mouse-ear hawkweed cover. On the unfertilised area mouse-ear hawkweed cover gradually increased reaching nearly 100% and remaining at or near that level from 1996 irrespective of pasture management. At the same site, mouse-ear hawkweed cover was assessed from three replicated sulphur trials each running from 3-6 years, and compared with accumulated dry matter. In all three trials the impact of reducing mouse-ear hawkweed cover equated to a doubling effect on dry matter yield, i.e. a halving in mouse-ear hawkweed cover was associated with a four fold increase in dry matter production. In this sunny facing country maintaining adequate sulphur fertility to encourage desirable pasture species and managing the grazing of this cover so it competes with mouse-ear hawkweed is seen as a good management option to grow more dry matter for animal production.

Additional keywords: sulphate sulphur, elemental sulphur, top-dressing frequency

Introduction

Hieracium spp. are hawkweeds and these introduced weeds are highly invasive with Espie (1994) estimating 42% of 15 million hectares of South Island high country is affected by hawkweeds. Although present since the 19th century the area has significantly increased up until the 1980's (Espie 1994, 2001), such that it has become a significant problem in New Zealand hill country. For example work at Tara Hills near Omarama showed mouse-ear hawkweed cover increased in low and mid altitude tussock country from 1984-1996 (Espie pers.comm.), although a recent popular press article suggested in Marlborough it is decreasing (Deavoll 2018). Opinion is divided as to why mouse-ear hawkweed has become a problem; Treskonova (1991) considered it a problem resulting from land degradation caused by burning, overstocking and rabbits, while Scott (1993) stated it is because mouse-ear hawkweed is an invasive weed and so it dominates in poorly fertilised and managed soils where it has no competition. At Tara Hills, Espie (pers.comm) found mouse-ear hawkweed outcompetes other resident plants for soil moisture and some nutrients and was less susceptible to soil acidity and high aluminium levels. The three most common *Hieracium* spp. in New Zealand are mouse-ear hawkweed, *Pilosella officinarum* (formerly known as *Hieracium pilosella*); King Devil hawkweed, (*P. piloselloides subspp. Praelta*); common in dryland and tussock land of the South Island high country respectively; and orange hawkweed (*P. aurantiaca*) more common in the North Island (Agpest Agresearch 2008-2018). Two further species, tussock hawkweed (*H. lepidulum*) and field hawkweed (*H. caespitosum*) also occur in New Zealand high country (Espie 2001). Mouse-ear hawkweed is of the greatest concern as it can produce stolons so is prostrate forming a mat that makes it hard for other plants to establish. Subsequent sward dry matter therefore remains low. It dominates open rangelands particularly in the Mackenzie country, particularly where land has not been cultivated. Subsequent pasture damage through overgrazing, irregular topdressing and high rabbit populations opens the pasture sward. Where rainfall and tussock cover are low, *hieracium* spp. are usually the first weed to colonise these areas.

Several agronomic control techniques have been trialled over the past decades. These include Allan Innes at Black Forest Station, Tekapo ripping the land by dragging a coarsely tined bar making pasture establishment easier through reduced competition. Similarly a robust direct drill 'Jethro Tull' (Tussock Grasslands Institute, Lincoln University) and rotary hoe drill (Scott 1993), drills which turn over part of the soil only, have been used with variable success. Moderate rates of glyphosate derived chemicals are known to kill mouse-ear hawkweed (NZ Agricultural Chem manual 2002) as is 2,4-D with clopyralid (Espie 1994) both with penetrants. Often these are not economic for extensive rangeland as they require multiple kills. 2,4-D with clopyralid may also cause damage to legumes, clopyralid has residual issues and the combination can be less effective on mouse-ear hawkweed. High rates of boron, >50kg/ha of fertiliser borate 48 (14.9% B) have also been tested to kill mouse-ear hawkweed by Millar (1994). Although these have beneficial residual effects in suppressing mouse-ear hawkweed, this is not economic and the longer term effect of boron toxicity on pasture establishment is unknown. In addition, biological control by rusts and powdery mildew are continually being assessed (Espie 1994).

In lieu of cultivation, the economic alternative to manage mouse-ear hawkweed is through controlled grazing and to use fertiliser to encourage alternative plant competition. It is well known that in tussock grasslands sulphur fertiliser is important to obtain adequate legume growth (Ludecke 1965). This paper draws on data from sulphur trials in the Mackenzie country in managing mouse-ear hawkweed. Data represents the broadcasting option rather than spray, cultivation and drilling options.

Materials and Methods

In the 1980's and 1990's the author supervised a series of trials involving the use of new sulphur based fertilisers. Many of these were trialled at a Ravensdown trial site at 'Mt.Thomas', in the Lindis Pass, a run off block owned by the Munro family of 'Rostreiver', Otamatata. The main trials were run on sunny facing fans adjacent to SH8, where sulphur rather than phosphorus was the more limiting factor to growth. The soils are Meyer, Pallic soils (Hewitt 1992), typical of the sunny facing fans, rolling and steepland soils of the South Island high country. The initial base fertility at the site was pH 5.6-5.8, Olsen P of 19-23, Quick Test (QT) Ca 6-7, QTK 7, QTMg 28 and SO_4-S of 2-3. Trials compared various sulphur products, rates and frequency of application. These ran from between 3 and 6 years and all were replicated four times in randomised block designs. As well as measuring dry matter (by mowing) 3-4 times/year, soil and herbage phosphate, sulphur and pasture composition were measured. In addition to grass and clover composition, in later trials mouse-ear hawkweed cover was also assessed. Trials received a seed mix containing alsike and white clover, with perennial ryegrass and Johnson tall fescue at the beginning of each trial plus sodium molybdate, 65 g/ha. Rainfall was measured and missing data supplemented by data from the nearby property 'Morven Hills' and Tara Hills Research Station, Omarama, Table 1. Dry matter and some soil and herbage data collated from this work has been previously published (Craighead and Metherell 2006) with products best described in a 'Sulphur' pamphlet (Ravensdown 1993). This paper splits mouse-ear hawkweed studies into two parts.

Table 1: Approximate annual rainfall at Mt.Thomas 1989-2006. Missing data has been supplemented by records from 'Morven Hills' and Tara Hills Research Station.

Year	Rainfall mm
1989	600
1990	615
1991	600
1992	530
1993	660
1994	860
1995	1005
1996	715
1997	530
1998	600
1999	540
2000	880
2001	495
2002	520
2003	470
2004	670
2005	460
2006	640

Mouse-ear hawkweed colony study

In this study data are presented from monitoring an area of significant mouse-ear hawkweed. This was part of an original eight treatment replicated sulphur trial where triennial application of 56 kgS applied in the spring proved the most effective treatment. Depending on the product, sulphur treatments produced 100-300% more dry matter than phosphate only controls. After the trial was completed, three adjacent plots (each 20 m^2) were monitored for mouse-ear hawkweed cover from 1992 until 2006, as this area contained significant hawkweed cover. These plots represented three treatments, a phosphate only control, elemental Sulphur and a bentonite sulphur plot. These were chosen for their proximity, both sulphur treatments growing significantly more dry matter than the P only control, $P<0.001$. These were not the highest producing sulphur treatments, sulphur fortified super products produced more dry matter (Craighead and Metherell 2006). From 1992, the bottom half of each plot was top-dressed every three years with 125 kg/ha of Ravensdown's Maxi Sulphur Super (0-5-0-50, containing 6% SO_4-S, 44% el S), before changing to Sulphur Super 30 (0-7-0-28, 10% SO_4-S, 18% el S) in 2004. These fertilisers provided 58 kgS/ha which approximates the minimum amount of sulphur, 54 kgS/ha, suggested by McIntosh and Sinclair (1983), as an initial application to establish clover on Pallic soils. The initial work at Mt. Thomas indicated that this amount of sulphur lasts between 2-3 years. Monitoring of mouse-ear hawkweed commenced in spring 1992 with two measurements/year, late spring and autumn. To do this a 10.8 cm x 10.8 cm grid was placed over each plot and scored solely as to whether mouse-ear hawkweed was present or absent within each grid cell, irrespective of whether pasture species were present. Plots were initially mown with most clippings returned after assessment, but from 2002 the site was opened to summer sheep grazing. Data are presented in Figures 1-3.

Sulphur trials

Mouse-ear hawkweed and treatment dry matter data are used from selected treatments from three mowing trials at the Mt. Thomas site. In two six year trials, a P only control receiving 70 kg/ha Triple Super (0-20-0-1) was compared with Sulphur Super 30 (0-7-0-28) treatments, both applied triennially (56 kgS/ha/application) and annually (19 kgS/ha), in trial 1,1989-1994, and in trial 2 the annual application was changed to biennial (38 kgS/ha) application, 1995-2001. There was a one year gap of measurements when continuing this trial. Treatment application rates were chosen to cover maintenance P requirements for typical sheep stocking rates used on this type of country (Cornforth and Sinclair 1984) and to supply variable rates and frequencies of sulphur. Plot sizes were 16 m^2 and treatments replicated four times (for more details refer to Craighead and Metherell 2006). In a third trial using smaller 4 m^2 plots, a P only control was compared with annually applied sulphate sulphur, at 6 and 12 kgS/ha/yr as gypsum. This ran from 1995 to 1999, for three and a half years. Total dry matter and mean mouse-ear hawkweed data are presented in Table 2. This area had not received S fertiliser for more than 10 years. Statistical analysis was by ANOVA using Minitab (Minitab Corporation, USA) and where applicable $LSD_{5\%}$ are given.

Results

Mouse-ear hawkweed colony

Initially in 1992, the mouse-ear hawkweed colony covered the mid to upper section of the former elemental S (left) and P only control (middle), with comparatively less in the bentonite S (right) plot, Figure 2. Mouse-ear hawkweed was present in 58%, 50% and 14% respectively of the grid cells. In the previous six years the bentonite treatment had produced significantly more dry matter than the elemental S treatment which in turn significantly out produced the P only control (Craighead and Metherell 2006).

In the first three year monitoring cycle, the colony gradually expanded where no sulphur was applied. The colony also slightly increased in the sulphur fertilised half, particularly in the third year when sulphur availability and hence clover dominance was declining, Figure 1. Previously published work from the site (Craighead and Metherell 2006) showed sulphur levels decline markedly in the third year after top-dressing reducing clover persistence and hence dry matter production, when the resident grasses make up a higher portion of the pasture sward. Retop-dressing the lower half of the plots in 1995 reduced the presence of mouse-ear hawkweed due to competition with re-dominant clover in particular making the mouse-ear hawkweed more upright in its growth habit so that on mowing much of this was removed. The 1994-1996 cycle was a wetter period (as also was 2000). Again the mouse-ear hawkweed area slightly increased in the third year after top-dressing as sulphur fertility declined. By 1996-97 grasses made up a significant part of the plots. On the untop-dressed area, the mouse-ear hawkweed colony continued to expand so that it was present in all of the first two plots and over 80% of the third plot by 1998. Further top-dressing in spring 1998 on the lower half of the plots showed a slight drop in mouse-ear hawkweed presence again with a slight increase again in the third year after top-dressing, as pronounced as in the previous two cycles. Over these three fertiliser cycles, mouse-ear hawkweed presence gradually increased in the top-dressed area, highlighting that any was a wetter period (as also was 2000). Again the mouse-ear hawkweed area slightly increased in the third year after top-dressing as sulphur fertility declined. By 1996-97 grasses made up a significant part of the plots. On the untop-dressed area, the mouse-ear hawkweed colony continued to expand so that it was present in all of the first two plots and over 80% of the third plot by 1998. Further top-dressing in spring 1998 on the lower half of the plots showed a slight drop in mouse-ear hawkweed presence again with a slight increase again in the third year after top-dressing, a pronounced as in the previous two cycles. Over these three fertiliser cycles, mouse-ear hawkweed presence gradually increased in the top-dressed area, highlighting that any decline in sulphur fertility enables the mouse-ear hawkweed to re-establish in previously clover dominant areas. By this stage on the unfertilised area mouse-ear hawkweed was present in at least 97% of all three initial plots.

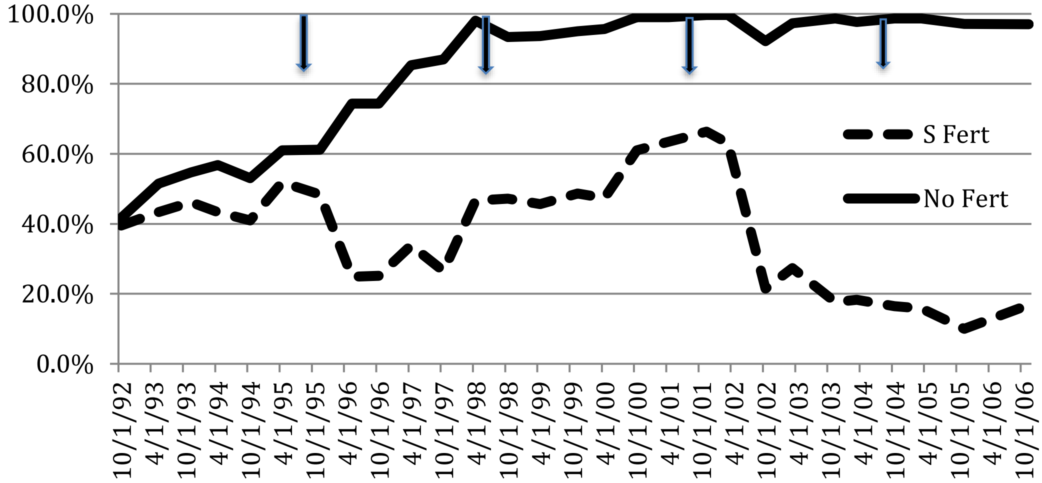

Figure 1: Comparison of % mouse-ear hawkweed cover, sulphur vs no sulphur 1992-2006 under mowing 1992-2001, and grazing 2002-2006. First top-dressing 1992, arrows represent when re top-dressed every three years.

Figure 2: Hawkweed presence on three previous treatments, elemental S, P only control and Bentonite S in 1992 before monitoring commenced.

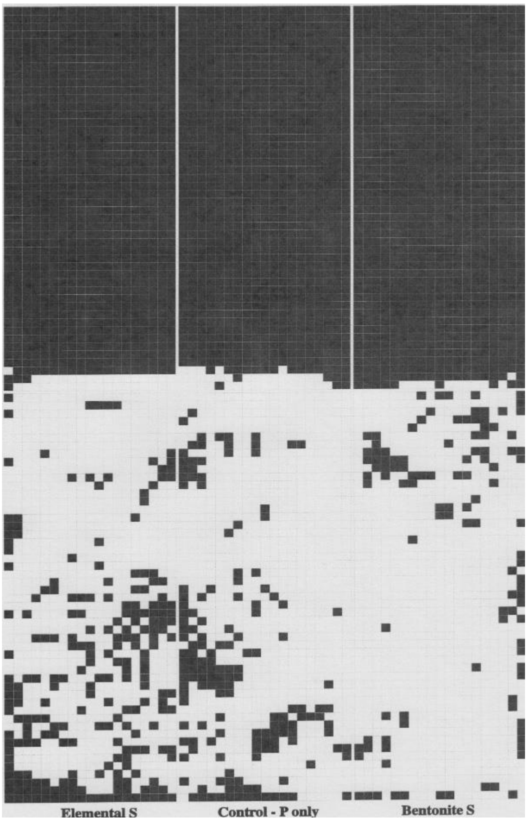

Figure 3: Hawkweed presence on three previous treatments in 2006 after lower half retop-dressed in spring 1992, 1995, 1998, 2001 and 2004 with 58 kgS/ha.

Table 2: Accumulative dry matter yield and mean mouse-ear hawkweed cover for selected treatments from three sulphur trials at Mt. Thomas, Lindis Pass. In all trials results are the means of four replicates.

Trial 1: 1989-1994				
Treatments	Control – P only	56 kgS/ha triennially	19 kgS/ha annually	Significance
Dry Matter kg/ha	4,675	20,570	18,530	$LSD_{5\%}$ 1495
Hawkweed cover	23%	8%	9%	$LSD_{5\%}$ 4
Trial 2: 1995-2001				
Treatments	Control – P only	56 kgS/ha triennially	38 kgS/ha biennially	Significance
Dry Matter kg/ha	2,745	21,555	22,035	$LSD_{5\%}$ 1990
Hawkweed cover	69%	13%	12%	$LSD_{5\%}$ 13
Trial 3: 1995-1999				
Treatments	Control –P only	6 kgS/ha annually	12 kgS/ha annually	Significance
Dry Matter kg/ha	2,770	5,710	11,585	$LSD_{5\%}$ 1685
Hawkweed cover	79%	56%	36%	$LSD_{5\%}$ 13

In 2002 the trial area was opened to grazing from early summer, by merino wethers and ewes, rather than mowing. It was not possible to isolate an area of nil grazing as the area was too small. Grazing coincided with a marked reduction in the presence of mouse-ear hawkweed where the plots were retop-dressed. This is likely to be because the flower heads would have been removed over summer by grazing, after spring mowing would have normally occurred. Prior to grazing being introduced, summer mowing only occurred if there had been significant rain. In autumn mowing would normally remove buds rather than flowers. Summer grazing has been suggested as the best strategy as bud removal promotes stolons which encourage *P. officinarum* persistence (Espie 1994). There was a 12 month delay in this occurring which may be due to 2001/02 being comparatively dry compared to most other years. There was minimal change in the presence of mouse-ear hawkweed in the third year after top-dressing and levels remained low for the remainder of the trial. Where no fertiliser was applied grazing had little effect on reducing mouse-ear hawkweed. This is demonstrated in Figure 2, the final cover in 2006. In the later years it was noticeable that while there were large individual white and alsike clover plants that responded to the sulphur, grass species became more dominant, particularly in the third year after retop-dressing. Over time some tall fescue and ryegrass was evident but the majority was existing species such as sweet vernal, browntop and fescue short tussock. Scott (2006) noted that even under oversowing, grass dominance occurred after about five years. Soil available nitrogen (AMN) tests partly explain why this happens, results presented in the previous paper (Craighead and Metherell 2006) showed a significant increase in soil AMN in sulphur treatments with clover establishment and so grasses would be expected to respond to the nitrogen fixed by the clover, increasing dry matter bulk.

Sulphur trials

Cumulative dry matter and the average presence of mouse-ear hawkweed are compared for selected treatments in three trials in Table 2. In all three trials pasture dry matter production was significantly higher $P<0.001$, than a P only control. In the first trial annual application of fertiliser also produced significantly less dry matter than triennial application but when this treatment changed to biennial application in trial 2 there was no difference in dry matter between biennial and triennial fertiliser application. In trial 3 the higher rate of sulphur, 12 kgS/ha/yr produced significantly more dry matter than 6 kgS/ha/yr, $P<0.001$.

Mouse-ear hawkweed was generally less prevalent in these trials compared to the colony study. In the first trial the presence of mouse-ear hawkweed remained between 14-36% for the control over the six years averaging significantly more ($P<0.001$) than the sulphur treatments which generally fell between 5 and 20%. In the control, mouse-ear hawkweed content did not change much throughout the trial but for the sulphur treatments it dropped gradually over time, a similar result to that noted in the colony study. A four fold increase in dry matter production with sulphur was associated with more than a halving in the presence of mouse-ear hawkweed.

In trial 2, mouse-ear hawkweed cover for the P only control, increased from 30% in the early years (a legacy of trial 1 treatments), to over 90% in the last two years, averaging 69% over the trial, significantly above the average for the sulphur treatments ($P<0.001$). For the sulphur treatments only a small amount of mouse-ear hawkweed was initially present. It increased through the intermediate years before varying from 5-33% in the last two years. The lower mouse-ear hawkweed contents were associated with a wetter 2000 year with values at the trial completion of 29 and 33% respectively, 2001 being one of the driest years. Dry matter production was the reverse of these trends. The herbage dry matter response to sulphur was greatest in this trial, primarily because most years were wetter than those observed in the first trial. On average sulphur treatments grew eight times the pasture dry matter production and this was associated with one fourth to one fifth the mouse-ear hawkweed cover. There was no significant difference in mouse-ear hawkweed content between the sulphur treatments in trials 1 and 2.

In trial 3, mouse-ear hawkweed presence was much higher at the start, and increased throughout the trial for the P only control and both sulphur treatments. There were significant differences ($P<0.001$) in the mouse-ear hawkweed content between the three treatments. Overall, sulphur reduced average mouse-ear hawkweed cover by one quarter and one half for the two treatments. For the 12 kgS/ha/yr again a four fold increase in pasture dry matter production was associated with a halving in mouse-ear hawkweed cover. The 6 kgS/ha/yr treatment doubled pasture dry matter production over the control for a 25% drop in mouse-ear hawkweed cover. It did not produce any more pasture dry matter in the first year than the control, but became significantly more responsive with time. Although low rates of sulphur grew significantly more pasture (in particular clover) dry matter, even 12 kgS applied /ha/yr was insufficient to maximise clover growth and fully suppress mouse-ear hawkweed under mowing conditions. Scott (2006) found a low annual rate (7-8 kgS/ha/yr) produced more pasture dry matter than 30 kgS/ha every four years, but acknowledged that maintenance fertiliser was not met.

Discussion

Dry matter and pasture cover

Based on the results from these three trials there appears be at least a doubling effect on pasture dry matter for each % that mouse-ear hawkweed cover is reduced. This is likely because mouse-ear hawkweed is prostrate and therefore any competition, particularly from upright grasses provides more bulk on a given area. Previous work (Espie 1994) showed this effect was more on upright *Hieracium* species such as king devil hawkweed rather than mouse-ear hawkweed, however the introduction of managed grazing is also essential. Allowing good pasture cover before grazing and grazing in summer rather than autumn has been shown by Espie 1994, at Tara Hills, Omarama and Scott (2006), Mt. John, Lake Tekapo to be the best way to combat mouse-ear hawkweed. Conversely over or continuous grazing does not allow the grass to regrow to shade out mouse-ear hawkweed so it remains dominant. It is essential that that soil fertility is adequate to encourage growth of competing pasture species, as demonstrated in these trials. Annual fluctuations in mouse-ear hawkweed cover and growth are also to be expected with varying rainfall, existing hawkweed cover, species and when the area was last fertilised. At Mt. John Scott (1993) found irrigation to minimise mouse-ear hawkweed cover even at low fertiliser inputs, as the grass and clover can compete more effectively for water and therefore smother the mouse-ear hawkweed. However in his trials Russell lupins were the dominant species rather than grasses and clovers as they can grow in low fertility situations. Lupins do not necessarily smother mouse-ear hawkweed and cannot always be grazed.

Seasonal variation

Recent comments in the media regarding a decline in hieracium (mouse-ear hawkweed) in the upper Awatere Valley, Marlborough (Deavoll 2018) suggest this is a natural occurrence. In these trials this has not noticeably occurred in control plots. This observation in Marlborough is likely to be because the past two seasons have been relatively wet on the back of three very dry seasons. In addition soil fertility had also been improved on many properties and oversowing has occurred on properties such as Molesworth Station, as farm managers gain a better understanding of how to graze hawkweed infested pasture. Results from these trials show that dry matter production varies with rainfall as does pasture composition (for individual data refer to Craighead and Metherell 2006) so that if retop-dressing coincides with a higher rainfall season, dry matter production especially of clover will be much greater. The annual rainfall at Mt. Thomas averaged 600-650 mm, with the range during the trials from <500 to >800 mm. Therefore in high rainfall situations, there will be more competition with mouse-ear hawkweed for light and nutrients and increased grazing and therefore hawkweed content will decline.

Dry matter responses to sulphur

Sunny facing fans and basins in the South Island high country often contain good phosphate levels, reasonable soil pH and low Aluminium levels (Al <2 mg/kg on the colony site). This work and subsequent development of a sunny basin on Mt. Thomas show these soils are highly responsive to sulphur fertiliser (and broadcasting of legumes), a much cheaper nutrient to apply than phosphorus. McIntosh and Sinclair (1983) obtained similar magnitude dry matter responses on the same soils to sulphur (sunny aspects) as well as similar responses on shady faces where high rates of phosphorus were also used. They considered these soils cover at least 650,000 ha of the South Island. Sulphur trials undertaken in other districts such as Marlborough also showed sulphur responses in the order of 25-60% (Craighead and Metherell 2006), however these Wither Hill, Pallic soils were more developed and mouse-ear hawkweed was only a minor component of the sward and sometimes not present. Dry matter responses by Scott et al; 2006 on moranic, glacial outwash, Tekapo (Brown) soils at Mt. John were intermediate between those at Mt. Thomas and the Wairau Valley, Marlborough.

Top-dressing frequency and sulphur rate

There are large areas of hill country where oversowing is not an economic or feasible option. As this is lowly stocked and often summer only grazing country, it is uneconomic to annually apply sulphur, particularly as most topdressing is by fixed wing aircraft and so application costs are expensive. Hence the main objective of the sulphur trials was to look at products and their breakdown to more evenly provide sulphur over extended frequencies of topdressing to reduce the overall application costs and to encourage grass and clover at the expense of mouse-ear hawkweed. In this respect biennial topdressing with highly fortified sulphur supers to supply 35-40 kgS/ha/application seems a better proposition than triennial application of 56 kgS/ha and is more likely to coincide with a wetter growing season. Given the magnitude of the dry matter (and pasture quality) responses, and the subsequent increase in stocking rates and the premium for fine merino wool, it would be economic to top-dress and lightly reseed this type of country every two to three years.

Scott *et al.,* (2006) showed lower dry matter responses than in his trials when comparing low rates of annual (25 kg/ha) vs four yearly application, (100 kg/ha) of initially Sulphur Super 30 and later Maxi Sulphur Super fertiliser. At Mt. John maintenance fertiliser was considered 100-150 kg/ha/yr of Sulphur Super 30, (30-45 kgS/ha/yr). On his site Scott considered the Ca in the Sulphur Super 30 to be at least as important as the P and S (soil Ca was 4.9-5.4 at year 4 compared to 6.7 at Mt. Thomas), Scott *et al.,* 2006. McIntosh and Sinclair (1983), suggested 200 kg/ha of Sulphur Super 30 (54 kgS/ha) was sufficient to give 70% of potential production over 3 years, while Boswell and Swanney (1991) suggested 50 kgS/ha applied biennially as sulphur fortified supers gave 90% of potential pasture production. In these trials 1 and 2 and the colony work, a similar amount of sulphur (56-60 kgS/ha) ran out during the third year, indicating the rate was inadequate or more likely the range of elemental sulphur particle sizes (and their subsequent oxidation) within the product was insufficient in the third year. Trial 3 showed an annual application of 12 kgS/ha was insufficient in this environment to fully manage mouse-ear hawkweed, possibly because there was insufficient fertiliser granules applied on the ground, and because no development sulphur fertiliser had been applied. While in trial 1 annual application of 19 kgS/ha performed well, this treatment probably lacked insufficient available sulphur at establishment (approximately 6 kg SO_4-S) to start the development process. The alternative may be to apply more S triennially, however this would have to contain a range of elemental S particles sizes that continually supply sulphate S through oxidation. It is difficult to tailor such a product to a specific site, as it will be used over a range of environment conditions where soil temperature and rainfall vary seasonally and with altitude. The sulphur super type products used here at the correct rates and timings, most closely meet these conditions.

While sulphur requirement may be lower in low rainfall and hence lower dry matter conditions, additional strategies such as long periods between grazings and regular clover seed addition may be required for broadcasting to be successful. The success of Scott's trials at Mt. John are related to oversowing by rotary hoe as much as fertiliser, irrigation and grazing management. Spraying has not been widely used, probably because it also affects desirable plants rather than solely mouse-ear hawkweed, so it probably best suits oversowing and other cultivation systems. In particular, in tussock grasslands it is important to retain as much tussock cover as you can to retain moisture and aid clover establishment while at the same time discouraging rabbit colonisation. The colony study highlights the likely impact of grazing on controlling mouse-ear hawkweed, however this had little impact unless sulphur was also used.

Conclusions

This work highlighted that on sunny facing high country, mouse-ear hawkweed can be managed using sulphur fertiliser. This is because sulphur encourages legume growth, resulting in longer term pastoral growth. This provides competition for mouse-ear hawkweed. In turn increased dry matter production means increased summer stock pressure which is the key to reducing seeding from mouse-ear hawkweed. Therefore the combination of well managed grazing and sulphur can severely limit or reduce the spread of mouse-ear hawkweed. The key is therefore to identify areas of the properties where this strategy can work and tailor the appropriate sulphur rates and frequency of topdressing (and legume reseeding) to this land.

Acknowledgements

The author wishes to acknowledge the Munro family for the use of their property and to Bill Burgess (deceased), Andy Howie and Steve Clark for assistance with field work. Dry matter data and initial mouse-ear hawkweed work comes from trial work undertaken while the author worked as the Ravensdown Agronomic Development Manager and was financed by both Ravensdown Fertiliser Co-operative Ltd and Nutrient Solutions Ltd.

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