Microsite effects on abundance of sown species on uncultivable slopes

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Abstract
Hill country has a vast array of microsites that may influence the success and uniformity of establishment of oversown pasture species and their persistence. In spring 2014, studies were conducted at Woodville (southern Hawke's Bay; summer-wet) and Cheviot (North Canterbury; summer-dry) to determine the effect of gentle (14-21°) and steep (32-40°) slopes on the presence and contribution to sward dry matter (DM) of oversown species in rotationally grazed swards aged 30 or 36 months. Gentle slopes had greater soil water content (29 versus 25%) and Olsen P (34 versus 26 µg/ml) than nearby steep slopes. Perennial ryegrass (94 versus 80%) and phalaris (6 versus 2%) were present in a greater proportion of plots on gentle than on steep slopes, respectively, whereas subterranean clover had a greater presence on steep than on gentle slopes (6 versus 1%). Perennial ryegrass comprised a higher percentage of DM in swards on gentle than on steep slopes (27 versus 11%). The percentage of DM contributed by other individual species did not differ significantly between slope classes. The persistence of most sown species was unaffected by slope; microsite variation was not a major influence on species persistence.

Keywords: hill country, microsites, pasture species, plant-microsite matches

Key messages
- Gentle slopes had greater Olsen P (34 versus 26 µg/ml) and volumetric soil water content (29 versus 25%) than adjacent steep slopes in spring.
- Perennial ryegrass had greater presence (94 versus 80%) and comprised a higher percentage of dry matter in swards (27 versus 11%) on gentle than steep slopes.
- The persistence of most sown species under rotational grazing after 30 or 36 months was unaffected by micro-scale differences in slope.

Introduction
There is a wide range of pasture species and cultivars adapted to different environmental conditions (Stewart *et al.* 2014) and a number of these have been evaluated in uncultivable hill country (>25° slope) over decades e.g. Chapman & Macfarlane (1985), Lambert *et al.* (1985), Scott *et al.* (1985) and Hampton *et al.* (1999). New cultivars of long-used species such as perennial ryegrass, cocksfoot, white clover, and red clover continue to be released and there has been increasing use of newer species such as plantain and chicory in seed mixes oversown on hill country. Variation between the myriad of microsites in hill country can result in non-uniform seedling establishment of sown species. Lambert *et al.* (1985) highlighted the potential value of introducing new germplasm to exploit the many different microsites and to allow for situations where germplasm in earlier oversowings established but did not persist, perhaps because of inappropriate management.

Establishment trials with a range of species and cultivars were commenced on uncultivable hill country throughout New Zealand in 2011/12 (Douglas *et al.* 2013; Tozer *et al.* 2013; Tozer *et al.* 2014). Moderate to steep hill country is characterised frequently by development of microsites such as areas of gentle (treads) and steep (scarps) slope angles depending on factors such as the extent and age of shallow land-sliding, and stock grazing pressures and movement. This study aimed to determine the effect of gentle and steep slopes on the presence of sown species and botanical composition in established swards. A further aim was to link plant and microsite environmental attributes to obtain greater understanding of interactions.

Materials and methods
Sites
Study sites were on uncultivable hill country near Woodville, southern Hawke's Bay, and Cheviot, North Canterbury. Woodville is a summer-wet environment with long-term (25 year) summer rainfall (December to February) of 177 mm and Cheviot is a summer-dry environment (127 mm, equivalent data).

Treatments
Four test swards and the resident sward (unsown, control) were selected in spring 2014, with the test swards aged 30 or 36 months. The test swards originated from oversowing a grass, legume and herb seed mix (GLH) in spring 2011 (sprGLH) and autumn 2012 (autGLH), and a legume-only seed mix (LEG) in spring 2011 (sprLEG)

ISSN 0110-8581 (Print) ISSN 2463-4751 (Online)

and autumn 2012 (autLEG) (Tozer *et al.* 2013; Tozer *et al.* 2014). The GLH mix comprised perennial ryegrass (*Lolium perenne*), cocksfoot (*Dactylis glomerata*), phalaris (*Phalaris aquatica*), grazing brome (*Bromus stamineus*), white clover (*Trifolium repens*), red clover (*T. pratense*), subterranean clover (*T. subterraneum*), plantain (*Plantago lanceolata*) and chicory (*Cichorium intybus*). The LEG mix comprised white clover, red clover, subterranean clover, birdsfoot trefoil (*Lotus corniculatus*) and lotus (*Lotus uliginosus* syn. *L. pedunculatus*). Cultivars and sowing rates are specified elsewhere (Tozer *et al.* 2013; Tozer *et al.* 2014). Each sward plot (experimental unit) was 10 x 10 m. Since sward establishment, all plots had been grazed 4- to 9-weekly with mixed-age sheep.

At Woodville, three replicate plots of the treatments were selected on the north and south aspects, whereas at Cheviot, three replicate plots of each treatment were selected only on the north aspect because this was the only aspect with variation in micro-slope angle. Within all selected plots, gentle (14-21^o slope angle) and steep (32-40^o) slopes were identified. Grazing ceased at Woodville on 6 October and at Cheviot on 5 November 2014.

Measurements

Herbage mass and botanical composition were determined at Woodville on 10 November (35 days after last grazing) and at Cheviot on 8 December (33 days). Herbage was harvested to ground level (<5 mm height) in four quadrat areas of 0.1 m^2 (250 mm x 400 mm) per plot, comprising two quadrats on each of gentle and steep slopes. Herbage was subsampled for dissection into categories of individual sown grasses, individual sown legumes, individual sown herbs, other grasses, other legumes, weeds and dead matter. All components and remainder were oven-dried (24 h at 70^{o}C). Growth rate of swards at each site was determined by harvesting herbage at the start (pre-growth) and end of the studies (Douglas *et al.* 2015).

Each quadrat area was measured for slope angle, aspect, volumetric soil water content (VSWC, 0-75 mm soil depth; mean of 5 readings), and soil chemistry (0-75 mm depth; bulked 8-10 cores each 25 mm diameter) comprising pH (1:2.1 v/v water slurry), Olsen phosphate (P, Olsen extraction), sulphate sulphur (SO_4-S; phosphate extraction), and 'Quick test' calcium (Ca), potassium (K), magnesium (Mg) and sodium (Na) using ammonium acetate extraction (Douglas *et al.* 2015).

Statistical analyses

Data for herbage mass, sward growth rate, VSWC, and soil chemical attributes were analysed using a split-plot analysis of variance in Genstat (VSN International 2014). Mean separation was achieved using Least Significant Difference (LSD) tests. Data were transformed where necessary and back-transformed means are presented to aid understanding.

There was a 2-stage analysis of the species data. Firstly, the presence/absence of each sown species in plots of the test swards, and the same species in plots of the resident swards, was determined assuming a binomial distribution with logit link function. Secondly, the percentage of each species in dry matter (DM) of swards was analysed using analysis of variance. For sown species where the data comprised many or all zeroes in specific factor combinations, those combinations were excluded from the analysis.

Separate canonical correlation analyses (Digby & Kempton 1987) were conducted for the Woodville and Cheviot studies using data for environmental parameters (slope, aspect, VSWC, soil chemistry attributes) and plant attributes (growth rate, masses of key sown species, other grasses, weeds, and dead matter) collected from control and GLH swards.

Results

Environmental parameters

Angles of steep slopes were almost twice those of gentle slopes on northern aspects at Woodville (WNTH; 40 versus 21^o) and Cheviot (CNTH; 32 versus 18^o), and 2.6-fold greater on the south aspect at Woodville (WSTH; 37 versus 14^o). Aspects of gentle and steep slopes were similar within location × aspect combinations (not presented).

The late spring moisture content at Cheviot (11% v/v) was considerably less than at Woodville (WNTH = 31%; WSTH = 46%). Soil pH was 5.2 (WNTH), 5.3 (WSTH) and 5.5 (CNTH) and Olsen P ranged from 27 µg/ml (CNTH) to 36 µg/ml (WNTH). Levels of SO_4-S at Cheviot (6 ppm) were about half those at Woodville, and K levels at Cheviot (24 Quick test units) were 4-fold greater than those at Woodville.

Gentle slopes had greater VSWC (29 versus 25%) and Olsen P (34 versus 26 µg/ml) than steep slopes. Results for pH, SO_4-S, Ca, K and Mg were inconsistent (location × aspect × slope interaction; $P<0.05$). For example, SO_4-S was greater on gentle than steep slopes at WSTH (12.3 versus 9.4 ppm) and CNTH (6.2 versus 5.5 ppm) whereas at WNTH, steep slopes had greater SO_4-S levels than gentle slopes (13.3 versus 11.8 ppm).

Herbage mass and growth rate

Herbage mass averaged 5.1 tonnes DM/ha at WNTH, 4.0 tonnes DM/ha at WSTH, and 3.5 tonnes DM/ha at CNTH. Sward growth rates at Woodville were 53 kg DM/ha/day on WNTH and 32 kg DM/ha/day on WSTH, exceeding those at CNTH (13 kg DM/ha/day). Herbage mass on gentle slopes was about 1.3-fold greater than on steep slopes (4.8 versus 3.6 tonnes DM/ha; P<0.001) and growth rate of swards on gentle slopes was twice that on steep slopes (44 versus 22 kg DM/ha/day).

Contribution of sown species

Perennial ryegrass was the only sown species present in at least 75% of plots and at CNTH, it was present in nearly all plots (Table 1). Presence of perennial ryegrass at WNTH and CNTH was significantly greater than at WSTH. Presence of cocksfoot was in the order WNTH > WSTH > CNTH. Grazing brome and phalaris were present in less than 10% of plots. Among sown legumes, white clover had the highest presence (62-80%). Red clover was present in approximately a quarter of plots at CNTH and negligible (WSTH) or absent (WNTH) elsewhere. Subterranean clover was detected in 10% of plots at CNTH and was absent at Woodville. Half the plots at WSTH contained *Lotus* spp. which was 5-fold greater than at CNTH. At least 4-fold more plots had chicory and plantain at CNTH than at Woodville (Table 1). Perennial ryegrass and phalaris were present in a greater proportion of plots on gentle than steep slopes whereas subterranean clover had 6-fold greater presence on steep than gentle slopes (Table 1). Slope had no effect on the presence of any other sown species. Results for individual swards are presented in Douglas *et al.* (2015).

Total sown species comprised the greatest percentage of sward DM at CNTH (26%), which was approximately twice that at WNTH and 4-fold greater than at WSTH. At WNTH, total sown species content in swards on gentle slopes was 3-fold greater than on steep slopes (26 versus 8% DM), whereas at WSTH (8 versus 5% DM) and CNTH (30 versus 23% DM), contents of total sown species on gentle and steep slopes were similar (location × aspect × slope interaction; P=0.014). The content of perennial ryegrass in swards was the highest of any sown species and at CNTH it was about 2-fold greater than at WNTH and 4-fold greater than at WSTH. The control sward at Woodville had an average content (% of DM) of 12% perennial ryegrass, 2% cocksfoot, 2% white clover, 1.5% *Lotus* spp. and 0.1% plantain. At Cheviot, content averaged 39% perennial ryegrass, 1% *Bromus* spp., 1% subterranean clover and 0.1% plantain. Across all swards, those on gentle slopes at WNTH had greater perennial ryegrass content than on steep slopes (30 versus 3% DM) whereas there were smaller differences in content between slope classes at WSTH (12 versus 5% DM) and CNTH (37 versus 26% DM) (location × aspect × slope interaction; P=0.009). Sward contents of other sown species were less than 5% of DM at all locations (Douglas *et al.* 2015).

The first canonical correlation at Woodville was 0.80 (P<0.001) and accounted for 23% of the total correlation between the environmental and plant datasets. Of the key attributes in the first canonical variates for each dataset, higher values of K, growth rate and mass of perennial ryegrass, and lower values of Olsen P and slope, tended to occur on gentle slopes (Figure 1a). Results for a significant second correlation are not presented because the variate for the plant dataset did not involve any sown species. At Cheviot, the first canonical correlation was 0.96 (P<0.01) and accounted for 16% of the total correlation between the environmental and plant datasets. Higher values of aspect, Olsen P, K, Na, and masses of perennial ryegrass and dead matter tended to occur on gentle slopes (Figure 1b). Other canonical correlations were not significant.

Discussion

The 3- or 4-fold greater pasture growth rates (only one growth period) at Woodville than at Cheviot were

Table 1 Proportion of plots with sown species present (%), across three location × aspect combinations.

	Perennial ryegrass (%)	Cocksfoot (%)	Grazing brome (%)	Phalaris (%)	White clover (%)	Red clover (%)	Subterranean clover (%)	*Lotus* spp. (%)	Chicory (%)	Plantain (%)
Location × aspect										
Woodville – North	89a[1]	75a	3	3b	80	0b	0b	31ab	3b	6b
Woodville – South	75b	47b	3	0b	62	3b	0b	50a	6ab	11b
Cheviot - North	97a	22c	8	8a	67	27a	10a	11b	25a	39a
P value[2]	0.006	<0.001	0.085	<0.001	0.157	<0.001	<0.001	0.012	<0.001	<0.001
Slope										
Gentle	94a	NA[3]	4	6a	71	11	1b	26	13	22
Steep	80b	NA	6	2b	68	9	6a	35	9	15
P value	0.007	NA	0.402	0.047	0.677	0.397	<0.001	0.361	0.411	0.252

[1]means with different letters differ at 5% level
[2]P = probability
[3]Not available because of computer analysis limitations

probably because of the relatively high soil water content found at Woodville rather than slight differences between sites in soil chemistry. The water content at Cheviot was likely near wilting point. Temperature might have also been influential given the difference in latitude between the sites, although in November/ December, this effect was likely small. Soil pH at the three location × aspect combinations and SO_4-S at CNTH were less than recommendations of 5.8-6.0 for pH and 10-12 ppm for SO_4-S (Morton & Roberts 2009), but these were unlikely to have explained the variation in growth rates.

Results were dominated by those for perennial ryegrass with the species being present in the highest proportion of plots and its content in herbage DM being greater than for any other sown species. It also showed a preference for gentle compared with steep slopes, probably because of their greater soil water content and greater soil P status. The low presence and sward content of grazing brome, phalaris and subterranean clover suggested that these species were only likely to be small contributors to sward DM in grazed, multi-species pastures in the longer term. At Woodville, the greatest presence and sward content of cocksfoot at WNTH and of *Lotus* spp. at WSTH suggested that it would be beneficial to add cocksfoot to seed mixes for northern aspects and *Lotus* spp. for southern aspects. It is recommended that red clover, chicory and plantain be included in seed mixes used in summer-dry environments because at Cheviot they were in at least 25% of plots in which they were sown, and they had greater contents in swards than at Woodville. Although red clover, chicory and plantain did not persist at Woodville as well as at Cheviot, there are numerous red and white clover and plantain pastures that have been established successfully on North Island hill country in the past few years.

The association between increasing slope angle and decreasing growth rate and mass of perennial ryegrass found at Woodville supported earlier findings (Gillingham *et al.* 1998; Lambert *et al.* 1983). Although high mass of perennial ryegrass was associated with low Olsen P values at Woodville and Cheviot, the lowest values found were unlikely limiting pasture growth (Morton & Roberts 2009). The positive canonical coefficients for K status at both locations and positive (Cheviot) or negative (Woodville) coefficients for Olsen P suggests variation between locations in the joint effect of these nutrients on growth of perennial ryegrass.

The effects of slope class on the abundance and growth of the sown species at Woodville and Cheviot should be interpreted cautiously because seedling and plant densities of sown species in each slope class were not measured earlier (Tozer *et al.* 2013; Tozer *et al.* 2014), including at the start of this study. Furthermore,

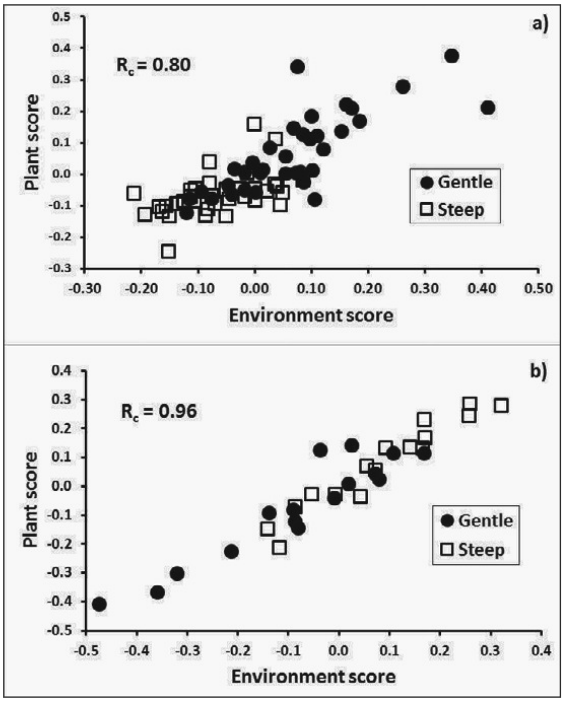

Figure 1 First canonical variate scores at a) Woodville (key plant attributes = growth rate and perennial ryegrass mass (both with positive canonical coefficients); key environmental attributes = slope (negative), Olsen P (negative), and K (positive)) and b) Cheviot (key plant attributes = masses of perennial ryegrass and dead matter (both negative); key environmental attributes (aspect, Olsen P, K and Na – all negative)). R_c = 1st canonical correlation.

potential differences in grazing of gentle and steep slopes by sheep during previous rotational grazing cycles, and other impacts of livestock such as treading damage and plant selection, could not be accounted for. The impact of the high covers at closing on species abundance was uncertain but did not invalidate the comparisons between gentle and steep slopes. The results indicated persistence of the sown species in each environment.

Conclusions

Environmental conditions varied between slopes at some or all location × aspect combinations. Perennial ryegrass and phalaris were present in a greater proportion of plots on gentle than steep slopes, whereas subterranean clover had greater presence on steep than gentle slopes. Perennial ryegrass comprised a higher % of total DM in swards on gentle than steep slopes. The lack of differences between slopes for presence and % of total DM of most sown species indicated that slope and associated environmental parameters were not significant factors influencing persistence of sown species.

ACKNOWLEDGEMENTS

Funding from Ministry of Business, Innovation and Employment, DairyNZ, Fonterra, Beef + Lamb New Zealand and DCANZ (Dairy Companies Association of New Zealand); advice on farmer needs from Beef + Lamb New Zealand; the managers and staff on whose properties the studies were conducted at Woodville and Cheviot.

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