Early performance of oversown pasture mixtures on non-cultivable hill country at four geo-climatically different sites

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Abstract

A trial was conducted on non-cultivable hill country (>20° slope) at four sites to determine the effect of seed mixture (grass+legume+herb vs legume) and sowing time (spring vs autumn) on plant establishment. Sites were in Canterbury (1 site), Hawke's Bay (2) and Waikato (1) on north and south aspects and differed predominantly in climate. In the first spring after sowing (12 months after spring sowing; 6 months after autumn sowing), sown legume and total sown species contributions (% of total dry matter (DM)) were: greater in the grass+legume+herb than legume mixtures; greater when sown in spring than autumn (15 vs 7% for sown legumes and 41 vs 21% for total sown species); and similar on north and south aspects. Sown grass contribution was greater from autumn than spring sowing (79 vs 65%) while sown herb contribution was greater from spring than autumn sowing (15 vs 1%), but both were similar across aspects. The contribution of unsown species was high, averaging 59% in spring-sown swards and 78% in autumn-sown swards. There was no effect of seed mixture or sowing time on DM production in spring (September–November; averaging 2660 kg DM/ha in Canterbury and 5080 kg DM/ha at a Hawke's Bay summer-moist site). However, DM production was greater in spring- than autumn-sown swards in summer at both sites (December–February; Canterbury: 1980 vs 1520 kg DM/ha; Hawke's Bay: 3980 vs 2670 kg DM/ha). In a wet year, broadcasting seed during spring rather than autumn is likely to result in the highest early DM production and contribution of sown species (sown grasses, legumes and herbs) in the sward. The high unsown species contribution emphasises the importance of dealing with the seed bank before establishment, especially when sowing in autumn.

Keywords: seed mixture; pasture establishment; botanical composition; unsown species ingress; pasture improvement.

Introduction

Steep, non-cultivable land below 1000 m is known in New Zealand as "hill country". It comprises about 40% of New Zealand's land surface and makes a significant contribution to the national economy (Blaschke *et al.* 1992). With on-going development of this country, there is potential to exploit new germplasm for particular regions and climates, which can improve feed supply in early spring through greater dry matter (DM) production and increased pasture quality. Previous research has focused particularly on legumes, to supply biologically fixed nitrogen (N) to the sward as N-limitation is a major issue in hill country pastures. From the 1960s to 1980s, numerous species and cultivars were trialled extensively (Chapman *et al.* 1985; Charlton & Henderson 1985; Suckling 1960). With the availability of new germplasm, and particularly the introduction and commercial use of forage herbs (Stewart *et al.* 2014), there has been a need to revisit pasture establishment practices and to determine which methods are most successful given different regions and climates.

Increasing the supply of high quality feed in early spring in non-cultivable hill country to increase live weight gains of lambs and rising 2-year-old cattle before weaning is a priority for Beef+LambNZ (Bray *et al.* 2013). One approach to achieving this is through establishing new plant genetics (Bray *et al.* 2013). Previous research was reviewed by us in 2011 to determine key practices directly related to establishing new pastures that influence establishment success of forage species. The most critical practices identified included aspect, time of sowing, seed mixture, cropping before sowing, herbicide use and grazing management after sowing. The review was the foundation for developing a national trial with 15 treatments at four locations. The trial aimed to determine which practices resulted in the greatest enhancement of high quality early spring feed in summer-wet and summer-dry areas, as measured by the greatest DM production and moderate to high pasture quality.

This included treatments involving seed mixtures (grass+legume+herb vs legume only to increase the chance of successful legume establishment), sowing time (spring vs autumn) and aspect (north vs south). Research sites were selected to provide a variety of soil, landscape and climate conditions and species were selected to represent what are commonly available on the market.

In a previous paper on this national trial (Tozer *et al.* 2013), we reported on the impact of sowing time and seed mixture on the number and percentage of seedlings that established. This paper reports botanical composition of these treatments and DM production in two of these sites in the first spring after sowing.

Methods

Sites

Details of the field sites, long-term rainfall and treatments are given in Tozer *et al.* (2013). In brief, sites were established in three North Island environments on hill country sheep and beef properties: summer-wet (Ngaroma, Waikato; 236 mm long-term (25 year) average summer rainfall (December to February)); summer-dry (Poukawa, central Hawke's Bay; 113 mm); and summer-moist (Woodville, southern Hawke's Bay; 177 mm); and in one South Island environment: summer-dry (Cheviot, Canterbury; 127 mm). Rainfall in summer 2011/2012 was above average for all sites. For summer 2011/2012, rainfall was 432 mm at Ngaroma, 207 mm at Poukawa, 284 mm at Woodville and 197 mm at Cheviot. Soil water deficits were calculated from data obtained from the NIWA virtual climate station database (Tait *et al.* 2006). Monthly rainfall and potential evapotranspiration data over the experimental period are shown in Figure 1. Sites were selected that had slope angles averaging >20^{o} and moderate to high soil nutrient status, e.g. pH >5.7, Olsen P >15 µg/g.

Treatments

At each site, on a north and a south aspect, seed mixtures of i) grass, legume and herb (GLH) and ii) legume only (LEG) were oversown by hand in spring 2011 (September) and autumn 2012 (March). On each aspect, these four treatments were arranged in four randomised complete blocks of 10 m × 10 m plots (experimental units). There was no replication of aspects at an individual site. The GLH mixture comprised a range of grasses, legumes and herbs: perennial ryegrass (*Lolium perenne*) cv. 'Grasslands Samson', cocksfoot (*Dactylis glomerata*) cv. 'Grasslands Tekapo', phalaris (*Phalaris aquatica*) cv. 'Grasslands Maru', grazing brome (*Bromus stamineus*) cv. 'Grasslands Gala', white clover (*Trifolium repens*) cv. 'Grasslands Bounty', red clover (*T. pratense*) cv. 'Grasslands Sensation', subterranean clover (*T. subterraneum*) cv. 'Denmark',

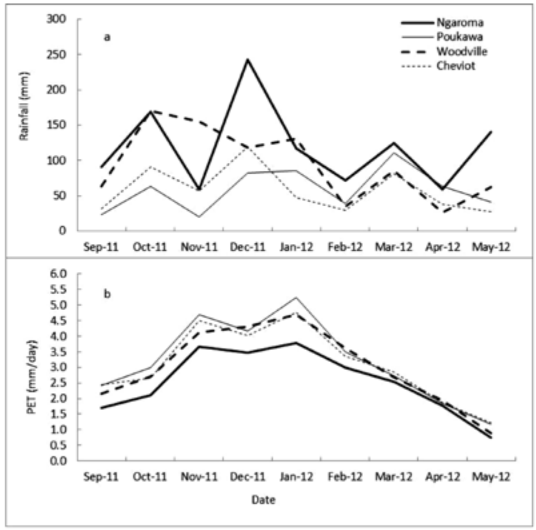

Figure 1a) Total monthly rainfall (mm); and b) potential evapotranspiration (PET; mm/day) for sites at Ngaroma (Waikato), Poukawa (central Hawke's Bay), Woodville (southern Hawke's Bay) and Cheviot (Canterbury). Data are from the NIWA virtual climate station database (Tait et al. 2006).

plantain (*Plantago lanceolata*) cv. 'Ceres Tonic' and chicory (*Cichorium intybus*) cv. 'Puna II'. The LEG mixture comprised the same cultivars of white clover, red clover, and subterranean clover included in the GLH mixture, and additionally birdsfoot trefoil (*Lotus corniculatus*) cv. 'Grasslands Goldie' and lotus (*Lotus uliginosus* syn. *L. pedunculatus*) cv. 'Grasslands Trojan'. Seed germination levels, sowing rates and establishment procedures are described in Tozer *et al.* (2013). Briefly, at all sites, plots were sprayed with glyphosate (ca. 2.0 kg a.i./ha) to kill resident swards, seed mixtures were sown by hand-broadcasting after which the seed was trampled by livestock (500 sheep/ha for 3 hrs) to increase seed-soil contact. Rotational grazing of all sites, mostly or exclusively with mixed-age sheep, occurred from six months after sowing in spring and autumn, with stocking rates, duration of grazing and time between successive grazings varying between sites.

Measurements and statistical analyses

In the first spring (September/October 2012), 6 months after sowing the autumn-sown treatments and 12 months after the spring-sown treatments, the percentages of sown grasses, sown legumes, sown herbs, broadleaf weeds and unsown grasses were assessed using the BOTANAL method (Nijland 2000; Tothill *et al.* 1992), using 20 randomly placed 0.1 m^2 rectangular quadrats in each plot. This method ranks the three most dominant species within each quadrat with respect to their visually estimated DM contribution. Multipliers were then used to estimate the percentage contribution to total DM of each pasture species. Multipliers were obtained experimentally using a combination of many hand-sorted data sets and statistical analyses of the data and are embedded within the BOTANAL procedure. The BOTANAL procedure is closely correlated with DM estimates obtained from hand sorting and weighing of harvested samples, non-destructive and much more rapid than hand-sorting (Lavorel *et al*. 2008; Waite 1994).

At the Cheviot and Woodville sites, herbage production was determined using a rising plate meter, randomly positioned 30 times within each plot. Assessments were made pre- and post-grazing during spring (September–November 2012) and summer (December 2012–February 2013). Pastures were grazed three times over this six month period.

Data were subjected to split plot analysis of variance in GenStat (2011), firstly including all sites in the analyses (treatments = 2 aspects × 2 sowing times × 2 seed mixtures) and then separate analyses for each site (treatments = 2 sowing times × 2 seed mixtures). The aspect treatment was applied to the main plots (hill sides), with the sowing time and seed mixture treatments applied to the sub-plots.

Results

When all sites were included in the analyses (Table 1), DM contribution of perennial ryegrass was lower on the north than south aspect. Dry matter contributions of red clover, total sown legumes and unsown grasses were lower in the GLH than LEG swards. Conversely, total sown species DM contribution was almost four-fold greater in the GLH than LEG swards. Dry matter contribution of white clover was greater when sown in spring than autumn, as was red clover, plantain, sown legumes, sown herbs and total sown species. The DM contribution of sown grasses was lower when sown in spring than autumn, and DM contribution of unsown grasses was also lower in spring-sown than autumn-sown swards. There were significant interactions between site and season for white clover, red clover, total sown legumes and total sown species, and significant site by mixture interactions for total sown species and unsown grasses (all P<0.05).

Key points for individual sites are described below.

Ngaroma: Dry matter contribution of sown legumes, unsown grasses and broadleaf weeds was lower in the GLH than LEG swards but DM contribution of total sown species was greater in the GLH than LEG swards (Table 2). Sowing time had a large impact on pasture composition, with a higher DM contribution from spring than autumn sowing for perennial ryegrass, white clover, red clover, chicory, plantain, sown grasses, sown legumes, sown herbs and total sown species. Unsown grass contribution was lower in swards sown in spring 2011 than autumn 2012 (Table 2).

Woodville: Botanical composition of swards followed

Table 1 Percentage of total dry matter (DM) for grass, legume and herb species in hill country, 6 months (autumn sown) or 12 months (spring sown) after sowing. Results are averaged across four sites in Waikato (1 site), Hawke's Bay (2) and Canterbury (1). At each site, seed mixtures of grasses, legumes and herbs (GLH) and legumes only (LEG) were sown on north and south aspects in spring 2011 and autumn 2012. Results are averaged across both aspects. SED = standard error of difference; *P<0.05; **P<0.01; ***P<0.001. '-' species absent.

Contribution (% of total DM)	Aspect			Sown mixture			Season		
	North	South	SED	GLH	LEG	SED	Spring	Autumn	SED
Ryegrass	20	33	3.1*	26	-		28	24	3.2
White clover	7	5	2.4	5	6	1.0	8	3	1.0***
Red clover	3	2	0.9	2	3	0.5**	4	1	0.5***
Plantain	5	5	2.7	5	-		9	1	1.7***
Sown grasses	32	35	8.5	33			65	79	3.2***
Sown legumes	13	9	4.3	9	13	1.6**	15	7	1.6***
Sown herbs	9	8	4.6	8			15	1	2.2***
Total sown	33	29	3.5	49	13	3.0***	41	21	3.0***
Unsown grasses	53	57	5.2	39	72	3.2***	46	64	3.2***
Broadleaf weeds	13	14	4.4	12	15	1.8	13	14	1.8

SED = standard error of difference; *P<0.05; **P<0.01, ***P<0.001

Table 2 Percentage of total dry matter (DM) for grass, legume and herb species on four non-cultivable hill country sites, 6 months (autumn sown) or 12 months (spring sown) after sowing. At each site, seed mixtures of grasses, legumes and herbs (GLH) and legumes only (LEG) were sown on north and south aspects in spring 2011 and autumn 2012. Results are averaged across both aspects. SED = standard error of difference; *P<0.05; **P<0.01; ***P<0.001. '-' species absent.

Contribution	**Sown mixture**			**Season**			**Sown mixture**			**Season**		
(% of total DM)	GLH	LEG	SED	Spring	Autumn	SED	GLH	LEG	SED	Spring	Autumn	SED
	Ngaroma						*Woodville*					
Perennial ryegrass	18			23	14	3.6*	26			24	27	3.1
Cocksfoot	2			4	1	1.7	3			4	2	1.5
Phalaris	-			-	-	-	-			-	-	-
Grazing brome	-			-	-	-	-			-	-	-
Lotus		1		1	0	0.5		3		2	4	1.6
Birdsfoot trefoil	-	-	-	-	-	-		-	-	-	-	-
White clover	4	4	0.9	7	1	0.9***	7	7	1.5	8	6	1.5
Red clover	1	2	0.5	2	0	0.5***	-	-	-	-	-	-
Subterranean clover	-	-	-	-	-	-	-	-	-	-	-	-
Chicory	4			8	0	1.2***	-			-	-	-
Plantain	5			9	0	0.8***	3			6	0	2.3*
Sown grasses	21			28	15	4.2**	30			29	31	3.7
Sown legumes	5	8	1.2*	10	2	1.2***	9	13	3.0	12	11	3.0
Sown herbs	9			18	1	1.5***	4			7	1	3.1*
Total sown	35	8	2.4***	33	9	2.4***	41	12	3.0***	28	24	3.0
Unsown grasses	41	61	2.0***	39	63	2.0***	51	79	4.0***	62	67	4.0
Broadleaf weeds	23	32	2.5**	28	27	2.5	6	8	1.2	6	7	1.2
	Cheviot						*Poukawa*					
Perennial ryegrass	32			35	28	4.2	28			28	28	4.5
Cocksfoot	-			-	-	-	-			-	-	-
Phalaris	-			-	-	-	14			16	12	5.7
Grazing brome	-			-	-	-	-			-	-	-
Lotus		-		-	-	-		-		-	-	-
Birdsfoot trefoil		-		-	-	-	-			-	-	-
White clover	5	8	1.6	11	1	1.6***	3	6	0.8***	6	4	0.8**
Red clover	3	5	1.3	7	1	1.3***	2	4	0.8	4	2	0.8*
Subterranean clover	4	4	1.1	3	4	1.1	3	2	1.1	3	2	1.1
Chicory	4			8	1	1.2***	4			7	0	1.2***
Plantain	5			9	1	1.3***	7			11	2	1.6***
Sown grasses	34			39	29	4.0*	47			54	40	6.0*
Sown legumes	11	18	2.3**	23	6	2.3***	9	14	1.7**	15	8	1.7***
Sown herbs	9			16	2	2.2***	11			18	3	1.7***
Total sown	54	18	3.6***	51	21	3.6***	66	13	3.3***	51	29	3.3***
Unsown grasses	39	72	3.8***	42	69	3.8***	23	75	3.6***	41	58	3.6***
Broadleaf weeds	7	10	1.6*	8	10	1.6	10	11	1.7	8	13	1.7*

a similar pattern to that at Ngaroma with a greater DM contribution of total sown species and lower unsown grass DM contribution in GLH than LEG swards. The DM contributions of plantain and sown herbs were both greater from spring than autumn sowing (Table 2). There was no effect of seed mixture or sowing time on DM production in spring 2012 (Table 3). In summer 2012/2013, DM production was greater in spring- than autumn-sown swards by 1.3 t DM/ha (3980 vs 2670 kg DM/ha).

Poukawa: Both summer-dry sites (Cheviot and Poukawa) followed similar trends. The DM contribution of white clover, sown legumes and unsown grasses was lower in GLH than LEG swards. Dry matter contribution of most vegetation components was significantly greater from spring than autumn sowing, including: white clover, red clover, chicory, plantain, sown grasses, sown legumes, sown herbs and total sown species. The DM contributions of unsown grasses and broadleaf weeds were lower in swards sown in spring than autumn (Table 2).

Cheviot: The DM contribution was lower in GLH than LEG swards for sown legumes, unsown grasses and broadleaf weeds, but greater in GLH than LEG swards for total sown species. Dry matter contribution was greater from spring than autumn sowing for white clover, red cover, chicory, plantain, sown grasses, sown legumes, sown herbs and total sown species. Swards sown in spring had lower contribution of unsown grasses than those sown in autumn (Table 2). There was no effect of seed mixture or sowing time on DM production in spring 2012 (Table 3). In summer 2012/2013, DM production was greater in spring than autumn-sown swards by 0.5 t DM/ha (1980 vs 1520 kg DM/ha).

Discussion

When results from all sites were considered, sowing time and seed mixture had the largest impact on DM contribution. There were consistent trends for a greater proportion of total sown species in swards when sown in spring than autumn (double the DM contribution) and in those established from sowing with the GLH than with the LEG seed mixture (over triple the DM contribution). The greater proportion of sown species in the GLH than LEG mixture is also consistent with seedling establishment data (14 vs 8% establishment in the GLH and LEG mixtures, respectively (Tozer *et al.* 2013), The greater sown species DM contribution in spring-sown swards was statistically significant for all sites except for the summer-moist site (Woodville), where spring and autumn sowing resulted in similar sown grass and legume contributions but greater sown herb contribution in spring-sown swards. However, summer herbage production at both Woodville and summer-dry Cheviot was greater from spring than autumn sowing, inferring that spring sowing remained the better option for all sites. There was less impact of aspect, with the only significant result being for perennial ryegrass, with a 1.5-fold greater DM contribution on the south than north aspect.

Total legume contribution was greater in swards established from sowing of the LEG seed mixture. The prostrate growth habit of white clover (which was the most prevalent legume), would make it vulnerable to shading in a tall, grass-dominated sward. Vulnerability to shading may also explain why the white clover contribution was either similar in both sward types or lower in GLH swards, even though the sowing rate of white clover was greater in the GLH than LEG seed mixture (2 vs 1 kg/ha). This also highlights how plant establishment may depend on the soil or climatic conditions to a greater extent than the sowing rate. Of

Table 3 Herbage production (kg DM/ha) in spring (September–November 2012) and summer (December 2012–February 2013) at the Cheviot and Woodville hill country sites, 6 months (autumn sown) or 12 months (spring sown) after sowing. At each site, seed mixtures of grasses, legumes and herbs (GLH) and legumes only (LEG) were sown on north and south aspects in spring 2011 and autumn 2012. Results are averaged across both aspects. SED = standard error of difference; ***P<0.001.

Site/Season	**Sown mixture**			**Season**		
(kg DM/ha)	GLH	LEG	SED	Spring	Autumn	SED
Cheviot						
Spring 2012	2570	2750	266	2760	2560	266
Summer 2012/13	1740	1760	100	1980	1520	100***
Woodville						
Spring 2012	5040	5120	279	5280	4870	279
Summer 2012/13	3270	3390	218	3980	2670	218***

note is the lack of birdsfoot trefoil, which was either not present or in amounts too small to detect, and most likely outcompeted by the other species present. Lotus was only detected in low proportions at the summer-wet sites, which is indicative of its lack of drought tolerance and also the inability of *Lotus* species to compete effectively with grasses in grass-dominant swards (Chapman *et al.* 1989; Charlton & Brock 1980). The proportion of legume in the LEG sward (13% of total DM) is consistent with Hume & Chapman (1993), who also observed a legume contribution of 13% of total DM, when legume seed was sown in swards treated with herbicide and where seed was trampled after sowing. The greatest sown legume contribution attained at any site was 18% of total DM at Cheviot, possibly because of the relatively low broadleaf weed contribution. As previously noted, the cultivars used in this study were unavailable when most of the previous research on hill country pasture establishment was done. To date, results from this study on establishment success of modern cultivars are consistent with those obtained using older grass and legume cultivars.

While there was variation between sites in sown species DM contribution (for example, ranging from 35% at Ngaroma to 66% at Poukawa in the GLH swards), trends were similar across sites. The proportion of perennial ryegrass in the sward ranged from 14% from autumn sowing at Ngaroma to 35% from spring sowing at Cheviot. While differences between sowing times in perennial ryegrass contribution were only significant at Ngaroma (in the individual site analysis), there was a trend towards a greater proportion of ryegrass from spring than autumn sowing across all sites. This was surprising given the much lower seedling establishment percentages of perennial ryegrass from spring than autumn sowing at both summer-dry sites (Cheviot and Poukawa) and similar establishment from spring and autumn sowing at Ngaroma (Tozer *et al.* 2013). There are at least two possible reasons for this. Firstly, spring-sown swards were established 6 months before the autumn-sown swards and results may reflect a greater build-up in ryegrass contribution over time in the spring-sown swards. The spring-sown plants would presumably have more tillers and be larger. Secondly, there was a far higher proportion of unsown species in autumn- than spring-sown swards. These would compete with the autumn germinating seedlings and suppress the growth of the sown species. Given the large DM contribution of unsown species present (averaging 78% of total DM in autumn and 59% in spring), the second reason is probably the most significant. The same reasoning would also apply to the trends in DM contribution of most other vegetation components (sown grasses, sown legumes, sown herbs), which were greater in swards sown in spring than autumn. The impact of livestock grazing on results is uncertain but issues of diet selection and more rotational grazing cycles on spring-sown than autumn-sown swards would have influenced treatment responses.

Other sown grass species made negligible or no contribution to sward DM. The DM contribution of cocksfoot was generally low, averaging only 3% at Ngaroma and Woodville and was not detectable at Cheviot and Poukawa. Phalaris was also not detectable at any of the sites other than Poukawa, where there was also resident phalaris seed in the seedbank, and grazing brome was not detected at any of the sites. Cocksfoot, phalaris and grazing brome DM contribution data are consistent with seedling establishment figures, which were also low and under 9% of total viable seed sown (Tozer *et al.* 2013).

Chicory and plantain were similarly minor components of the sward (ranging from 3 to 7% depending on the site), and chicory was not detected at Woodville. The greater DM contribution of forage herbs when sown in spring may also be explained by the lower unsown grass contribution in swards sown in spring than in autumn. For example, Stewart (1996) noted that plantain is vulnerable to competition from grasses; it was most likely suppressed due to the high unsown grass contribution in this trial.

While aspect has been shown to influence pasture establishment and growth because of differences in attributes such as soil moisture content and soil temperature (Charlton 1977; Gillingham 1973; Lambert & Roberts 1976), the higher than average rainfall during the establishment phase and high proportion of unsown species present in the swards may have overridden effects of aspect.

Several conclusions can be drawn. Firstly, while legumes may establish better when sown alone, this sequence is likely to lead to a low proportion of sown species in the sward because of emergence of unsown species (principally grasses) from the seedbank and ingression from other sources. Secondly, establishment with one herbicide application before sowing appears inadequate to deal with the seedbank and subsequent growth of unsown species – current monitoring will reveal if two herbicide applications can overcome this problem. Thirdly, unsown species that emerge from the seedbank are able to alter seedling establishment trends such that establishment from spring- rather than autumn-sown seed resulted in the greatest DM contribution of sown species at the summer-wet site (Ngaroma) and at both summer-dry sites. This was despite seedling establishment of sown species being greater from autumn than spring sowing in the summer-dry environments. Finally, the benefits of spring sowing were supported by greater herbage production in summer 2012/2013 in the spring- than autumn-sown swards, in both the summer-moist and summer-dry environments. The wetter than average 2011/2012 summer following spring sowing would have assisted pasture establishment, particularly at the drier sites.

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