# Pasture establishment on non-cultivable hill country

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## Abstract
To determine the best method of pasture establishment on non-cultivable hill country (>20$^o$ slope), four treatments were compared in one year on north and south aspects at four sites with contrasting climates and soil types. Sites were located in Waikato (1), Hawke's Bay (2) and Canterbury (1). The treatments included seed mix (grasses, legumes and herbs (GLH); legumes only (LEG)) and sowing time (spring; autumn). Six weeks after sowing, seedling establishment, as a percentage of viable seeds sown, was: i) greater on south than north aspects for perennial ryegrass (31% vs 18%) and birdsfoot trefoil (5% vs 4%); ii) greater for total sown species (14% vs 8%), subterranean clover (7% vs 4%) and red clover (25% vs 14%) in the GLH than LEG mix, but greater for white clover in the LEG than GLH mix (17% vs 8%); iii) greater in autumn than spring for perennial ryegrass (36% vs 13%) and total sown grasses (22% vs 9%) but greater in spring than autumn for lotus (6% vs 3%). Plantain established well in spring in summer-wet environments, while in summer-dry environments establishment was greater in autumn. Broadcasting seed on south aspects during autumn is likely to result in the highest establishment of sown grasses and legumes, but not necessarily of herbs. The trials were conducted in an unusually wet season. Repeating a subset of the treatments at these sites will provide a greater understanding of responses to climatic variation.

**Keywords:** pasture renewal; pasture establishment; pasture mixtures; oversowing.

## Introduction
Establishing pasture species from seed in New Zealand non-cultivable hill country is challenging, mainly because of its steep and variable topography and harsh climate. Steep, non-cultivable country below 1000 m a.s.l comprises at least 40% of New Zealand's total land area and is commonly known as hill country (Blaschke *et al.* 1992). There has been much previous research on establishing pasture species on non-cultivable hill country (Chapman *et al.* 1985; Charlton & Henderson 1985; Suckling 1960). However, land use change, as flatter land is increasingly developed for dairy and hill country for drystock, in addition to the availability of new plant germplasm, has led to renewed interest in establishing new pastures. It is expected that these pastures will increase productivity and feed quality in these landscapes. Establishment of legumes is particularly important because legumes provide a nitrogen source that will help to maintain soil fertility and support growth and survival of accompanying sown grasses and herbs.

In response to this focus, key practices that influence pasture establishment in non-cultivable hill country were used to design a nationwide trial series on this terrain. This paper reports on the establishment of species sown in four of these treatments on two aspects at four sites, 6 weeks after sowing.

## Methods
### Sites
Sites were established in three North Island environments: summer-wet (Ngaroma, South 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, North Canterbury; 127 mm). Sites at Ngaroma and Cheviot were on commercial sheep and beef properties, whereas the Woodville site was at AgResearch's Ballantrae Hill Country Research Station and the Poukawa site was at the Poukawa Research Station. For summer 2011/2012, rainfall was 432 mm at Ngaroma, 207 mm at Poukawa, 284 mm at Woodville and 197 mm at Cheviot. Rainfall in summer 2011/2012 was above average for all sites. Monthly rainfall data over the experimental period are shown in Figure 1. Average long-term (approx. 30 years) soil water deficits in summer ranged from 28 mm (Ngaroma) to 45 mm (Cheviot). Soil water deficits were calculated from data obtained from the NIWA virtual climate station database (Tait *et al.* 2006). Sites were selected that had slope angles averaging 25$^o$ and moderate to high soil nutrient status with a pH of 5.6, Olsen P of 29 µg/ml,

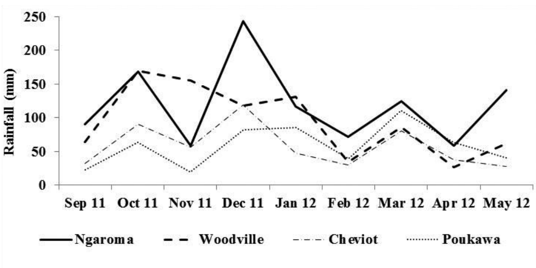


**Figure 1** Total monthly rainfall for sites at Ngaroma (South Waikato), Poukawa (central Hawke's Bay), Woodville (southern Hawke's Bay) and Cheviot (North Canterbury). Data are from the NIWA virtual climate station database (Tait *et al.* 2006).

K of 11 MAF Quicktest units (MAF QT), $SO_4$-S of 12 ppm, Ca of 5 MAF QT, Mg of 23 MAF QT and Na of 5 MAF QT (when averaged across all sites). All sites were established on silt loam soils.

## Treatments and seed mix

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 sown 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).

The GLH mix comprised perennial ryegrass (*Lolium perenne*) (7 kg/ha), cocksfoot (*Dactylis glomerata*) (1.5 kg), phalaris (*Phalaris aquatica*) (1.5 kg), grazing brome (*Bromus stamineus*) (8 kg), white clover (*Trifolium repens*) (2 kg), red clover (*T. pratense*) (3 kg), subterranean clover (*T. subterraneum*) (2 kg), plantain (*Plantago lanceolata*) (0.5 kg) and chicory (*Cichorium intybus*) (0.5 kg). The LEG mix comprised white clover (1 kg), red clover (3 kg), subterranean clover (3 kg), birdsfoot trefoil (*Lotus corniculatus*) (1 kg) and lotus (*Lotus uliginosus* syn. *L. pedunculatus*) (0.7 kg). Germination of all sown lines was between 89% and 97%. All legume seed was inoculated with appropriate *Rhizobium* strains. Plots were sprayed with glyphosate (at an average rate of 1.98 kg a.i./ha) 7–10 days before sowing to kill resident swards. The seed mixes were broadcast by hand and livestock (500 sheep/ha for 3 hrs) were used to trample seed into the ground within several days of sowing to increase seed-soil contact using the method suggested by Hampton *et al*. (1999).

## Measurements and analysis

Seedlings were counted 6 weeks after sowing in ten 0.2 $m^2$ quadrats per plot. Data were expressed as seedlings/$m^2$ and the percentage of each species established was calculated as percentage of viable seed/$m^2$.

Data were subject to split plot analysis of variance, firstly including all sites in the analyses (treatment

**Table 1** Effects of aspect, seed mixture and season on establishment (% of total number of viable seeds sown) of grass, legume and herb species on non-cultivable hill country, 6 weeks after sowing. Results are averaged across sites in South Waikato (1 site), Hawke's Bay (2), and North Canterbury (1); at each site mixtures of grasses, legumes and herbs (GLH) and legumes (LEG) were established on north and south aspects in spring 2011 and autumn 2012.

| Species | Aspect | | | Sown mix | | | Season | | |
|---|---|---|---|---|---|---|---|---|---|
| | North | South | SED | GLH | LEG | SED | Spring | Autumn | SED |
| Perennial ryegrass | 18 | 31 | 4.0* | 24 | | | 13 | 36 | 9.8* |
| Cocksfoot | 2 | 3 | 1.2 | 2 | | | 2 | 3 | 1.1 |
| Phalaris | 12 | 4 | 8.7 | 8 | | | 6 | 9 | 3.7 |
| Grazing brome | 13 | 5 | 10.3 | 9 | | | 7 | 11 | 6.4 |
| Lotus | 4 | 6 | 1.0 | | 5 | | 6 | 3 | 1.5* |
| Birdsfoot trefoil | 4 | 5 | 0.3* | | 5 | | 4 | 6 | 1.4 |
| White clover | 10 | 14 | 1.8 | 8 | 17 | 2.9** | 12 | 13 | 2.9 |
| Red clover | 16 | 23 | 7.5 | 25 | 14 | 5.5* | 25 | 14 | 5.5 |
| Subterranean clover | 5 | 6 | 1.9 | 7 | 4 | 1.1** | 7 | 5 | 1.1 |
| Chicory | 9 | 11 | 3.4 | 10 | | | 13 | 7 | 2.7 |
| Plantain | 14 | 29 | 8.3 | 22 | | | 26 | 18 | 8.4 |
| | | | | | | | | | |
| Sown grasses | 13 | 18 | 2.1 | 16 | | | 9 | 22 | 5.6* |
| Sown legumes | 8 | 11 | 1.3 | 11 | 8 | 2.0 | 11 | 8 | 2.0 |
| Sown herbs | 11 | 18 | 5.1 | 14 | | | 17 | 11 | 4.6 |
| Total sown | 9 | 13 | 1.3 | 14 | 8 | 2.5* | 10 | 12 | 2.5 |

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

combinations = 2 aspects × 2 sowing times × 2 sowing mixes) and then separate analyses for each site (treatment combinations = 2 sowing times × 2 sowing mixes).

## Results

When all sites were included in the analyses (Table 1), perennial ryegrass establishment was greater on the south than north aspect (31% vs 18%) and in autumn than spring (36% vs 13%). Establishment of cocksfoot, phalaris or grazing brome was not significantly affected by aspect or sowing time. Total sown grass establishment was higher in autumn than spring (22% vs 9%). Of the sown legumes, lotus establishment was greater in spring than autumn (6% vs 3%) and birdsfoot trefoil establishment was greater on the south than north aspect (5% vs 4%).

For the sown legume species in GLH and LEG mixes, establishment of white clover was greater when sown in the LEG than GLH mix (17% vs 8%), while

**Table 2** Establishment (% of total number of viable seeds sown) of grass, legume and herb species on four non-cultivable hill country sites, 6 weeks after sowing. At each site, mixtures of grasses, legumes and herbs (GLH) and legumes (LEG) were established on north and south aspects in spring 2011 and autumn 2012. SED = standard error of difference; *P<0.05; **P<0.01; ***P<0.001.

| Establishment % | Sown mix | | | Season | | | Sown mix | | | Season | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | GLH | LEG | SED | Spring | Autumn | SED | GLH | LEG | SED | Spring | Autumn | SED |
| | Ngaroma | | | | | | Woodville | | | | | |
| Perennial ryegrass | 16 | | | 16 | 15 | 2.8 | 15 | | | 25 | 5 | 3.6*** |
| Cocksfoot | 3 | | | 5 | 1 | 0.7*** | 1 | | | 1 | <1 | 0.3* |
| Phalaris | 4 | | | 5 | 2 | 1.9 | 0 | | | 0 | 0 | - |
| Grazing brome | 3 | | | 4 | 1 | 1.2** | 8 | | | 11 | 4 | 2.2** |
| Lotus | | 5 | | 7 | 3 | 1.9* | | 9 | | 15 | 3 | 2.46*** |
| Birdsfoot trefoil | | 6 | | 5 | 8 | 3.4 | | 6 | | 6 | 6 | 1.6 |
| White clover | 4 | 10 | 1.6*** | 10 | 4 | 1.6*** | 13 | 23 | 3.2** | 26 | 10 | 3.2*** |
| Red clover | 10 | 8 | 1.6 | 15 | 3 | 1.6*** | 51 | 23 | 4.7*** | 64 | 10 | 4.7*** |
| Subterranean clover | 2 | 2 | 0.5 | 5 | <1 | 0.5*** | 6 | 2 | 1.3** | 5 | 2 | 1.3* |
| Chicory | 11 | | | 18 | 4 | 1.8*** | 12 | | | 18 | 5 | 3.0*** |
| Plantain | 18 | | | 31 | 5 | 5.2*** | 30 | | | 53 | 6 | 4.6*** |
| Sown grasses | 10 | | | 11 | 9 | 1.8 | 9 | | | 15 | 4 | 2.0*** |
| Sown legumes | 5 | 6 | 0.8 | 8 | 2 | 0.8*** | 20 | 11 | 1.9*** | 25 | 6 | 1.9*** |
| Sown herbs | 13 | | | 23 | 4 | 2.6*** | 18 | | | 31 | 5 | 3.1*** |
| Total sown | 8 | 6 | 0.9** | 9 | 5 | 0.9*** | 14 | 11 | 1.3* | 19 | 5 | 1.3*** |
| | Cheviot | | | | | | Poukawa | | | | | |
| Perennial ryegrass | 15 | | | 2 | 29 | 5.1*** | 52 | | | 9 | 94 | 10.9*** |
| Cocksfoot | 1 | | | 1 | 1 | 0.5 | 5 | | | 2 | 8 | 0.7*** |
| Phalaris | 2 | | | 1 | 3 | 1.6 | 24 | | | 18 | 30 | 11.0 |
| Grazing brome | 20 | | | 1 | 40 | 7.9*** | 5 | | | 10 | 1 | 1.6*** |
| Lotus | | 3 | | 2 | 5 | 1.5 | | 3 | | 3 | 3 | 1.0 |
| Birdsfoot trefoil | | 4 | | 2 | 6 | 1.4** | | 2 | | 2 | 3 | 0.8 |
| White clover | 7 | 13 | 2.1** | 9 | 10 | 2.1 | 8 | 22 | 4.6** | 4 | 26 | 4.6*** |
| Red clover | 25 | 14 | 5.4* | 14 | 26 | 5.4* | 14 | 9 | 3.1 | 5 | 18 | 3.1*** |
| Subterranean clover | 6 | 4 | 1.4 | 5 | 5 | 1.4 | 15 | 8 | 3.2* | 11 | 12 | 3.2 |
| Chicory | 8 | | | 8 | 8 | 1.6 | 10 | | | 7 | 13 | 4.7 |
| Plantain | 8 | | | 5 | 10 | 2.7 | 32 | | | 13 | 50 | 6.5*** |
| Sown grasses | 11 | | | 1 | 20 | 3.0*** | 33 | | | 9 | 57 | 6.0*** |
| Sown legumes | 10 | 7 | 1.5* | 7 | 10 | 1.5 | 10 | 8 | 1.7 | 5 | 13 | 1.7*** |
| Sown herbs | 8 | | | 7 | 8 | 1.8 | 18 | | | 9 | 27 | 4.5*** |
| Total sown | 10 | 7 | 1.3** | 5 | 12 | 1.32*** | 23 | 8 | 2.2*** | 6 | 25 | 2.2*** |

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

red clover and subterranean clover establishment were greater when sown in the GLH than LEG mix (red clover: 25% vs 14%; subterranean clover: 7% vs 4% for GLH and LEG mixes, respectively). Establishment of all sown species was greater in the GLH than LEG mix (14% vs 8%). There were few interactions between the mix sown and season or aspect. Variation between sites was much greater than within a site. Key points of difference for individual sites are described below.

*Ngaroma*: Establishment of total sown grasses was similar in spring and autumn, averaging 10% (Table 2), with perennial ryegrass having the highest establishment percentage of any of the grasses sown (16% for perennial ryegrass vs 3% or 4% for cocksfoot, phalaris and grazing brome). Establishment of chicory, plantain and total sown herbs was greater in spring than autumn (sown herbs: 23% vs 4%) as was white clover, red clover, subterranean clover, lotus and total sown legume establishment (sown legumes: 8% vs 2%). Of the legumes, average establishment percentages were highest for white clover and red clover (7% and 9%, respectively). White clover established best when sown in the LEG than GLH mix (10% vs 4%). Establishment of all sown species was greater in the GLH than LEG mix (total sown: 8% vs 6%).

*Woodville*: Establishment followed a similar pattern to Ngaroma with greater establishment from spring than autumn sowing for perennial ryegrass, cocksfoot, grazing brome, sown grasses (15% vs 4%), chicory, plantain, sown herbs (31% vs 5%), white clover, red clover, subterranean clover, lotus, total sown legumes (25% vs 6%) and all sown species (19% vs 5%) (Table 2). White clover establishment was greater in the LEG than GLH mix (23% vs 13%) while establishment of red clover and subterranean clover was greater when these legumes were sown in the GLH than LEG mix (sown legumes: 20% vs 11%). Total sown legume establishment and total sown species establishment were also greater in the GLH than LEG mix (total sown species: 14% vs 11%).

*Cheviot*: Establishment was greater in autumn than spring for perennial ryegrass (29% vs 2%), grazing brome (40% vs 1%), total sown grasses (20% vs 1%), birdsfoot trefoil (6% vs 2%), red clover (26% vs 14%) and total sown species (12% vs 5%) (Table 2). Establishment of white clover was greater when sown in the LEG than GLH mix (13% vs 7%) while red clover establishment (25% vs 14%) was greater in the GLH than LEG mix. Total sown legume establishment (10% vs 7%) and total sown species establishment (10% vs 7%) were also greater in the GLH than LEG mix (Table 2).

*Poukawa*: Establishment was greater in autumn than spring for perennial ryegrass (94% vs 9%), cocksfoot (8% vs 2%), plantain (50% vs 13%), white clover (26% vs 4%), red clover (18% vs 5%), total sown grasses (57% vs 9%), total sown legumes (13% vs 5%), total sown herbs (27% vs 9%) and total sown species (25% vs 6%) (Table 2). White clover establishment was greater in the LEG than GLH mix (22% vs 8%) while establishment of subterranean clover and total sown species was greater in the GLH than LEG mix (subterranean clover: 15% vs 8%; total sown species: 23% vs 8%, Table 2).

## Discussion

When results from all sites were considered, season of sowing and seed mixture had the largest impact on establishment, based on the number of significant differences. Establishment was greater in autumn than spring and total establishment was greatest in the GLH mix. In particular, establishment of perennial ryegrass was nearly three times as great in autumn as spring, with over one-third of seed sown establishing in autumn but only 13% in spring, when the onset of drier conditions most likely impeded perennial ryegrass establishment.

In contrast to red clover, which established well in the GLH mix, white clover had greater establishment when sown in the LEG mix. The growth habit of white clover is more prostrate than red clover (Charlton & Stewart 2006; Kemp *et al.* 1999) and white clover would more easily be shaded in a grass-legume mix. Subterranean clover normally germinates in the autumn, although in this study its establishment was low, averaging 6% in both the autumn and spring sown treatments. Total legume establishment across the four sites ranged from 5%–20% of legume seed sown, with white clover (4%–23%) and red clover (8%–51%) having the highest establishment percentages. Chapman *et al.* (1985) found that white clover losses during emergence were 4%–18% of the seed sown and many seedlings died after seedling emergence. High losses were also documented by Hume & Chapman (1993), who found only 13% establishment from sowing legume seed in swards treated with herbicide and where seed was trampled after sowing.

At all sites except Poukawa, 15% or 16% of sown perennial ryegrass seed produced seedlings. The more than three-fold greater establishment of perennial ryegrass at Poukawa (52%) reflected the large perennial ryegrass seed bank, which was verified by high perennial ryegrass establishment in the LEG plots. Phalaris and cocksfoot establishment were generally low, other than at Poukawa where there was also resident phalaris in the seed bank.

There was much variation between sites in sown species establishment, most likely because of differences in climate. Sites were selected for their moderate to high soil nutrient status and therefore nutrient deficiencies were unlikely. At both summer-dry sites (Cheviot and Poukawa), establishment of mixtures was better in autumn than spring. At the sites with higher summer rainfall (Woodville and Ngaroma), establishment of species in spring was similar to or greater than establishment of species in autumn. For example, at summer-moist Woodville, 53% of sown plantain seed produced seedlings from spring sowing while only 6% established from autumn sowing. This is the reverse of results at summer-dry Poukawa, where only 13% established from spring sowing and 50% from autumn sowing. Plantain has been shown to establish rapidly and is drought tolerant, although it is vulnerable to competition from other species (Stewart 1996). Results from this study are consistent with this.

Broadcasting seed on the south aspect enhanced establishment of perennial ryegrass and birdsfoot trefoil compared with sowing on the north aspect. Previous studies have shown that aspect can be important; further monitoring will most likely be required for effects of aspect to become evident. For example, at Woodville, Charlton (1977) found that 15 months after sowing, survival of most sown species was greater on north-facing slopes than shady, south-facing slopes, with the exception of lotus, which had higher survival on south aspects. North aspects are typically drier than south aspects, especially over summer (Gillingham 1973; Lambert & Roberts 1976), which can often lead to poor pasture establishment on north aspects in summer-dry areas. The summer rainfall after sowing in this study was higher than average so that an aspect effect may not have been as pronounced as in drier years. Treatments will be repeated at similar sites in the following years, which will give a more robust indication of the impact of aspect on establishment of species under a range of climatic conditions. In a more usual (drier) season, results may have been different. While there were significant differences between treatments, the overall establishment percentages were low, despite the wet summer. These low percentages illustrate the difficulties faced when establishing pastures in non-cultivable hill country. In lowland areas, establishment percentages are typically higher (Hampton *et al.* 1999).

Monitoring of botanical composition and dry matter (DM) production is continuing for several years at all sites to determine which combination of aspect, time of sowing and seed mixture gives the best sown species establishment, DM production and botanical composition when compared to the existing pastures. Additional treatments, including the number of herbicide applications before sowing, cropping with brassicas before sowing and grazing management after sowing, are also being investigated and a subset of treatments will be repeated in 2013/2014.

## Conclusion

Grasses and legumes generally establish best in autumn on south aspects, although pasture species may establish better when sown in spring in summer-wet areas, given average or above-average rainfall. Further, white clover is likely to be suppressed in a seed mix containing grasses, legumes and herbs and may establish best if sown before the grasses. Repeating the most promising treatments will enable determination of the extent to which climate may affect the results. This is especially important given that the year in which this study was taken was an exceedingly wet season with higher than average rainfall during the establishment period. While recommendations cannot be made at this stage, the establishment data presented indicate the potential of each species to contribute DM to the sward. Greater DM production of sown species will increase productivity in hill country pastures, providing there is high utilisation of the DM produced.

## ACKNOWLEDGEMENTS

Funding from Ministry of Business, Innovation and Employment, Dairy NZ, Fonterra, Beef + Lamb New Zealand and DCANZ; advice on farmer needs from Beef + Lamb New Zealand; the managers and staff on whose properties the trials were established, at Ngaroma, Poukawa, Woodville and Cheviot.

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