

Legumes for South Island tussock grassland environments - an evaluation of plant survival and growth at some inland Otago and Canterbury trials

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Abstract

Many legumes have been trialled for establishment, persistence and productivity in the tussock grassland region of the South Island, New Zealand. This paper presents information on long-term persistence and growth based on a survey of surviving legume species from 45 previous plant accession trials, established over a range of sites and environments (predominantly dryland) throughout Otago and Canterbury. Sites were visited in January/February 2003 and identified plants were visually scored for several growth-related parameters. Most sites were open to stock grazing and all were affected by drought during the current growing season.

Of the legume species that seed is not commercially available for in New Zealand, the most persistent and vigorous were: *Lupinus polyphyllus*, *Trifolium medium*, *Coronilla varia*, *Dorycnium hirsutum*, *Melilotus alba* and *M. officinalis*, *Astragalus falcatus*, *T. canescens*, *D. pentaphyllum*, and *A. cicer*. These plants may usefully supplement tussock grassland vegetation under environmental and management conditions including periodic drought and the moderate to light grazing experienced at most of the trial sites visited. This paper reviews growth and survival of those legumes, and provides a guide to species with potential for revegetation in dryland and semi-arid environments that warrant further research into site x management interactions and possibly commercial development.

Key words: legume persistence, Otago/Canterbury, revegetation, tussock grassland

Introduction

The objective was to survey legume species across a range of (mainly) mid-altitude hill country trial sites in Otago and Canterbury, particularly those within drier environments, and identify those that have persisted and/or grew well. Those legumes may then

be considered for inclusion in tussock grassland revegetation programmes, or to assist with pastoral improvement when management and site factors are further defined. Most trials pre-date the change to Foundation for Research, Science and Technology based research funding and, although many have been discontinued, the information available from them is still considered relevant to pastoral farming given their relative longevity and, in many cases, exposure to 'normal' grazing management practice.

Research trials including legumes were initiated in the early 1900s in the Mackenzie Basin and Central Otago and have been described in the surveys and reports of McPherson, McGillivray, Cockayne, Calder, Zotov and others, documented chiefly in early volumes of the New Zealand Journal of Agriculture. These included single species from seed or plants, and some trials with multiple species mixtures.

During the 1980s and 1990s, on-farm agricultural and soil conservation research and technology transfer was conducted by the former Ministry of Agriculture & Fisheries, Department of Scientific & Industrial Research, and Ministry of Works & Development - Water & Soil Division, now largely combined into AgResearch. Various reviews and papers relating to this plant introduction work have been published; Wills (1984), Scott *et al.* (1995), van Kraayenoord & Hathaway (1986), Chapman *et al.* (1989), Woodman *et al.* (1992, 1996), Douglas *et al.* (1996) and Scott (2001).

Comprehensive technical documentation was also distributed in association with the numerous MRDC/MAF/AgR field days held at properties like Belfield (Hakataramea Valley, 1991), Glenfoyle, Ardlui, Earnsclough (Central Otago, 1992) and North Otago (1992). This paper provides updated information for several of these trials and an indication of future perspective relating to possible legume application based consideration of current and historical results.

Methods

Seventeen sites in Central Otago (schistose base material) and the Mackenzie Basin (greywacke) were visited in January/February 2003. These were comprised of 45 separate trial plots including Central Otago: Bendigo (five plots), Galloway (two), Earnsclough-Omeo (three), Earnsclough-Shepherds Flat (four), Northburn-Cockayne (10); and Mackenzie/Waitaki: Haka-Belfield (one), Otematata (three), Stony Creek (one), Black Forest (one), Haldon Airstrip (one), Sievwright-Holbrook (one), Tara Hills (four), Glentanner (one), Ben Ohau (one), Ruataniwha (one), Wolds (one), Mt John (several). Site location and 30 year normal rainfall data (Tomlinson & Sansom 1994) for the nearest meteorological stations are detailed in Table 1.

Table 1 New Zealand Map Series 260 site references and long term normal annual rainfall (mm) of nearest meteorological station.

Site	Reference	Rainfall (Site)
Bendigo	G41 223801	401 (Cromwell)
Mid-Galloway	G42 388434	412 (Clyde)
Top-Galloway	G42 433338	597 (Blackstone Hill)
Earnsclough-Omeo	G42 178453	412 (Clyde)
Earnsclough-Shepherds Flat	G42 145484	412 (Clyde)
Northburn-Cockayne (Top plot)	G41 162672	401 (Cromwell)
Haka-Belfield	I42 139113	535 (Waitaki)
Otematata	H40 860159	535 (Waitaki)
Stony Creek	I39 614414	646 (Twizel)
Black Forest	I39 949371	646 (Twizel)
Haldon Airstrip	I39 922469	646 (Twizel)
Siewwright-Holbrook	I38 118781	646 (Twizel)
Tara Hills (Red Flat)	H39 622264	546 (Tara Hills)
Tara Hills (hill)	I39 641246	546 (Tara Hills)
Glentanner (top)	H37 764962	854 (Braemar)
Ben Ohau	H38 821586	646 (Twizel)
Ruataniwha	H38 744581	646 (Twizel)
Wolds	I38 979758	597 (Tekapo)
Mt John	I37 061188	597 (Tekapo)

The majority of trial plots ranged in size from 0.25-1.0 ha. although some, like Bendigo and Mt John, covered several hectares. Earnsclough, Northburn

and Glentanner sites comprise several small plots totalling 2-5 ha. They cover a wide range of altitude, from 300-1 200 m above sea level with most plots in the 400-700 m range and receive 400-650 mm annual rainfall (Table 1). The high Glentanner sites were the exception with 850 mm annual rainfall, but it was considered expedient to include them in the survey due to their proximity to other Mackenzie Basin trials.

Approximately 40% of the trial species surveyed were drilled or oversown, the remainder being hand-planted, thus a range of establishment technique was represented. Site maintenance and management had changed considerably since the original trials were evaluated. Fences were either down or removed with only a few sites left intact and ungrazed (specifically the Sievwright, Black Forest, Haldon, and one high altitude Glentanner, plots).

All others had some degree of grazing, either recent or historic, with open access to stock (and rabbits) from adjacent farm blocks. Grazing and fertility over the past decade or more have been determined by standard management of those farm blocks and, although not necessarily ideal for the legume species, it now represents a 'real world' situation.

At the assessment in 2002/2003, most sites were unstocked (since at least December 2002) and few rabbits were noted. Exceptions included Ben Ohau (rabbit numbers were high and *T. arvensis* was dominant), Ruataniwha (Merino sheep were grazing in the vicinity), and Earnsclough-Shepherds Flat (cattle had access from paddocks enclosing the trial plots). Part of one plot at Otematata was open and had

been grazed recently. Most sites contained several species with a range of palatability. All were well represented in the survey results (Tables 3, 4), not just those normally considered 'less palatable' as

might be expected if sites had been heavily and/or recently grazed.

At each site, a record was made of the legume species present, and the height and spread of representative plants was measured. For uniformity of assessment across differing sites, plant vigour, survival and productivity were visually scored. Scoring was done on a '0' to '3' basis (modified from Haydock & Shaw 1975). A '0' score indicated plants were not growing (low vigour), there were few present (poor survival), or little foliage was present (low productivity). Only extremely vigorous (growing actively at time of assessment), numerous (based on original plantings or seeding) or productive (having accumulated substantial forage, not necessarily fresh) plants recorded a maximum score of '3' in each category. Limited plant growth caused by the dry seasonal conditions precluded effective use of a wider scoring range (eg. 0-5).

aspect plot was divided into 2 m wide strips that were traversed, noting plant numbers for identifiable legume species. Plant numbers were totalled for each replicate and standard errors of the means were calculated for this data. Legume plant height and spread were also measured and those data were combined with plant number data to give an approximation of the percent plant groundcover and plant foliar volume. A similar calculation was also carried out for hard tussock, *Festuca novae-zealandiae*, as a grassland comparison. This was based on the height and spread of typical local stands of hard tussock, which had a density of about 1 plant/m².

Due to the considerable variation in site, species, environment and management, statistical analysis (standard errors of the mean) was only carried out for data from the replicated Earnsclough - Shepherds Flat, sunny aspect plot.

Table 2 Monthly rainfall (mm) at Clyde, Tara Hills and Tekapo Airport, July 2002 to May 2003.

Month	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Total
Clyde	6	36	29	24	36	41	57	19	9	16	25	298
Tara	22	37	55	5	36	38	46	34	10	11	54	318
Tekapo	28	57	96	23	51	41	35	39	20	13	83	486

Each species plot, group or area within a trial site was ranked for vigour, survival and productivity. If replication was evident, sub-plots were scored separately and a site mean was obtained. This information was entered into a spreadsheet and sorted by the appropriate parameter (vigour or survival or productivity, or a combination) prior to tabulation. Height and spread data were not used in the sorting.

An 'accelerated screening trial', designed to evaluate 'persistence attributes' in a wide range of grasses and legumes, was established in 1992 at Earnsclough Station (Fraser 1992), Tara Hills and Mt John. This only remained intact at Earnsclough Station - Shepherds Flat where stock (cattle) had access to the sunny, shady and neutral aspect plots. While it was not possible to accurately define the original pegged plot layout, the four replicates within each trial were still identifiable. The sunny aspect plot there contained several legume species, thus a more detailed survey of it was justified to define long-term plant survival and growth.

Each replicate (approximately 0.1 ha) in the sunny

Results

Precipitation

Monthly and total rainfall records for Clyde, Tara Hills and Tekapo Airport during the past growing season are presented in Table 2. They provide an indication of seasonal precipitation, which can be compared to the 30-year normal records for selected regional stations (Table 1).

Legume survival

Across all trial sites, nine genera recorded the highest survival ranking of '3'. These were represented by some 15 species (Table 3), the majority of those being from the genus *Trifolium* with five species (including *T. ambiguum*, *T. arvense*, *T. hybridum*, *T. medium* and *T. repens*) growing at several sites. Although these plants were all characterised by high survival, their rankings for vigour and productivity were variable. Sites with a high survival ranking for two or more legume species included Bendigo, both Earnsclough sites (Omeo and Shepherds Flat), Mt John, Stony Ck, Glentanner (lower) and mid-Galloway.

Table 3 Site, altitude, age and establishment method of legume species that recorded the highest survival ranking (3) from trial plots assessed in 2003.

Establishment site	Altitude (m)	Years established	Binomial	Method
Ben Ohau - Acheron Flats	450	25-30	<i>Trifolium arvense</i>	R
Bendigo	390	17-27	<i>Dorycnium hirsutum</i>	D
			<i>D. hirsutum</i>	P,D
Earnsclough AccScr Flat	600	10-11	<i>T. arvense</i>	R
Earnsclough AccScr Sunny	600	10-11	<i>Coronilla varia</i>	P
			<i>Lotus corniculatus</i>	P
			<i>T. arvense</i>	R
			<i>T. repens</i>	P
Earnsclough AccScr Shady	590	10-11	<i>T. ambiguum</i>	P
			<i>T. arvense</i>	R
			<i>T. repens</i>	P
Earnsclough-Omeo	270	10-11	<i>Astragalus cicer</i>	P
			<i>A. falcatus</i>	P
			<i>D. hirsutum</i>	P,D
			<i>D. pentaphyllum</i>	P,D
			<i>Melilotus alba</i>	P
			<i>M. officinalis</i>	P
Glentanner (Lower Chalet)	840	28-30	<i>T. ambiguum</i>	P
			<i>L. corniculatus</i>	P,O/S
Mid-Galloway	500	10-20	<i>Lupinus polyphyllus</i>	S
			<i>D. hirsutum</i>	O/S
Mt John	760	8-12	<i>T. ambiguum</i>	O/S
			<i>Lotus corniculatus</i>	P,O/S
Northburn-Cockayne	600	80	<i>Lupinus polyphyllus</i>	P,O/S
			<i>T. arvense</i>	R
			<i>T. medium</i>	P,O/S
			<i>Medicago sativa</i>	O/S
Otematata	490	20-25	<i>T. medium</i>	P
Siewwright-Holbrook	670	60	<i>D. pentaphyllum</i>	P,O/S
Stony Creek	750	19	<i>T. medium</i>	P
			<i>A. falcatus</i>	P
			<i>D. hirsutum</i>	P
Tara Hills-Keoghan	520	20	<i>D. pentaphyllum</i>	P
Top-Galloway	790	20-30	<i>T. arvense</i>	R
Wolds	640	30-35	<i>T. ambiguum</i>	O/S
			<i>T. hybridum</i>	O/S
			<i>T. repens</i>	O/S

AccScr = Accelerated Screening trial. Establishment method includes D = drilling, O/S = oversown/seeded, P = hand planted, R = resident. NB. vigour and productivity rankings varied (compare Table 5).

Table 4 Failed legume species with identified establishment method(s) and reason(s) for failure (where known).

Binomial	Site	Yrs Established	Method	Comments
<i>Astragalus cicer</i>	Bendigo	1976-86	Drilled	Seed germination failed
<i>A. cicer</i>	Bendigo	1976-86	Plants	Failed after 2-3 yrs, drought
<i>A. cicer</i>	Top-Galloway	1983-93	Plants, drilled	Seed germination failed, cold temperatures
<i>A. falcatus</i>	Top-Galloway	1983-93	Plants, drilled	Seed germination failed, cold temperatures
<i>A. glycyphyllos</i>	Top-Galloway	1983-93	Drilled	Seed germination failed, cold temperatures
<i>Dorycnium rectum</i>	Bendigo	1976-86	Plants	Drought failure
<i>D. rectum</i>	Top-Galloway	1983-93	Seed	Seed germination failed
<i>D. rectum</i>	Otematata	1978-93	Plants	Drought stressed, frosting?
<i>D. rectum</i>	Stony Creek	1991-92	Plants	Frost failure?
<i>D. suffruticosum</i>	Bendigo	1976-86	Plants	Drought failure
<i>Hedysarum coronarium</i>	Bendigo	1976-86	Drilled	Seed germination failed
<i>H. coronarium</i>	Bendigo	1976-86	Plants, seed	Drought failure
<i>H. coronarium</i>	Otematata	1978-93	O/S seed	Drought and frosting failure
<i>Lotus caucasicus</i>	Top-Galloway	1983-93	Drilled	Seed germination failed
<i>L. corniculatus</i>	Acheron Flats	1973-78	O/S Seed	Originally L. cornic. dominant, many rabbits
<i>L. corniculatus</i>	Ruataniwha	1975-82	O/S Seed	Originally L. cornic. dominant, now vernal.
<i>L. corniculatus</i>	Wolds	1968-73	Plants, seed ?	From KF O'Connor trial, not identified
<i>L. tenuis</i>	Bendigo	1976-86	Drilled	Failed after 2-3 yrs, drought
<i>Lupinus polyphyllus</i>	Bendigo	1976-86	Drilled	Failed after 1st yr, drought
<i>L. polyphyllus</i>	Bendigo	1976-86	Plants, seed	Drought failure
<i>L. luteus</i>	Bendigo	1976-86	Plants	Drought failure
<i>Medicago sativa</i>	Top-Galloway	1983-93	Seed	Failed after 1st yr, cold temperatures
<i>M. sativa</i>	Earnsclough A/S [†] Flat	1992-93	Plants	Not identified
<i>M. sativa</i>	Wolds	1968-73	Plants, seed ?	From KF O'Connor trial, not identified
<i>M. varia</i>	Top-Galloway	1983-93	Drilled	Seed germination failed
<i>Melilotus alba</i>	Top-Galloway	1983-93	Drilled	Seed germination failed
<i>M. officinalis</i>	Bendigo	1976-86	Drilled	Failed after 4-5 yrs, poor reseeding
<i>M. officinalis</i>	Top-Galloway	1983-93	Drilled	Seed germination failed
<i>Onobrychis viciifolia</i>	Bendigo	1976-86	Drilled	Seed germination failed
<i>O. viciifolia</i>	Bendigo	1976-86	Plants	Drought failure
<i>Ononis pusilla</i>	Bendigo	1976-86	Plants	Drought failure
<i>Trifolium ambiguum</i>	Bendigo	1976-86	Plants	Drought failure
<i>T. ambiguum</i>	Otematata	1978-93	Plants	Drought stressed, frosting?
<i>T. fragiferum</i>	Earnsclough A/S Flat	1992-93	Plants	Not identified
<i>T. hybridum</i>	Top-Galloway	1983-93	O/S Seed	Good initially, now sparse, requires fertility
<i>T. medium</i>	Top-Galloway	1983-93	Drilled	Seed germination failed
<i>Vicia sativa</i>	Earnsclough A/S Flat	1992-93	Plants	Not identified
<i>V. sativa</i>	Earnsclough A/S Shady	1992-93	Plants	Not identified

[†] = Accelerated screening plots

Table 5 Legume species at identified sites recording highest vigour ranking (3), sorted (in descending order) by survival and productivity ranking with associated plant height/spread (cm), phenology and comments.

Binomial	Site	Altitude	Survival	Height	Spread	Productivity	Phenology	Comments
<i>Astragalus falcatus</i>	Stony Creek	750	3	65	180	3	SD	Minor die-back, drought or late frost
<i>Dorycnium hirsutum</i>	Mid-Galloway	500	3	35	50	3	FL, FR-	Plants and seed good
<i>D. pentaphyllum</i>	Stony Creek	750	3	45	100	3	FL, FR	Plants good, no seedlings noted
<i>Lupinus polyphyllus</i>	Glentanner-Lower	840	3	45	35	3	FL-, FR, SD	Ex pelleting trial, numerous seedlings
<i>L. polyphyllus</i>	Mt John	760	3	35	45	3	FR, SD	Dominant legume, some drought stress
<i>Melilotus alba</i>	Earnsclough-Omeo	270	3	150	60	3	FL+	Vigorous, reseeded from drilling
<i>Trifolium medium</i>	Cockayne-Plot 12	900	3	30	300	3	SD+	Tops drought stressed, also in Plot 9 in 1995
<i>T. medium</i>	Siewwright-Holbrook	670	3	40	2-300	3	SD+	Drought stressed
<i>D. pentaphyllum</i>	Otematata	490	3	50	100	2	V	Some reseeded, cold and drought tolerant
<i>M. officinalis</i>	Earnsclough-Omeo	270	3	100	50	2	FL+	Vigorous, reseeded from drilling
<i>T. medium</i>	Mt John	760	3	20	300	2	V	Several large patches ex Mason trial
<i>D. pentaphyllum</i>	Earnsclough-Omeo	270	3	40	60	2	FL+, FR-	Little reseeded, but v cold and drought tolerant
<i>Lotus corniculatus</i>	Stony Creek	750	2	30	60	3	V	Minor die-back, frost?
<i>Lupinus polyphyllus</i>	Siewwright-Holbrook	670	2	65	55	3	FR, SD	Drought and late frost stress showing
<i>L. polyphyllus</i>	Glentanner-Scotts Nth1250		2	40	35	3	SD-	OK, ex 1970s seeding
<i>T. pratense</i>	Siewwright-Holbrook	670	2	45	65	3	FL-, SD+	Minor drought stress
<i>A. falcatus</i>	Mid-Galloway	500	2	25	55	2	FR-, SD	Plants OK, seed germination failed
<i>D. hirsutum</i>	Otematata	490	2	70	120	2	SD	Reseeding, plants dying but cold/drought tolerant
<i>Lotus corniculatus</i>	Glentanner-Scotts Nth1250		2	25	20	2	FL-	Many seedlings in SW corner of plot
<i>L. corniculatus</i>	Otematata	490	2	45	80	2	V	Some drought stress, leaf yellowing
<i>D. pentaphyllum</i>	Bendigo	390	2	35	50	2	FL, FR	Generally healthy
<i>Medicago sativa</i>	Cockayne-Plot 7	600	1	45	30	3	FL	Few plants, dominated by tall oat grass
<i>L. pedunculatus</i>	Glentanner-Scotts Nth1250		1	30	25	2	FL+	Patch in NE corner of plot

Phenology: V = vegetative, FL = flowering, FR = fruiting, SD = seeding. +/- = more or less than average.

Legume genera that recorded a moderate survival ranking ('2') included *Trifolium* with seven species, *Astragalus* (four spp), *Coronilla* (one spp), *Dorycnium* (three spp), *Lotus* (two spp) and *Lupinus* (two spp).

Other surviving species only recorded a low-ranking (1): *Astragalus* (four spp), *Coronilla* (one spp), *Dorycnium* (one spp), *Lotus* (two spp), *Medicago* (two spp), *Trifolium* (six spp). Species known to have failed (11 genera and 22 spp) are outlined in Table 4. These failed to survive or thrive for various reasons, presumably related to site adaptability. Where known, the reasons recorded were usually 'germination failure', 'drought failure' or 'frost failure'. Although all legumes in open plots showed evidence of grazing, some more recent than others, grazing was not commonly cited as a reason for failure.

Legume vigour

Plants with the highest ('3') vigour ranking recorded a '3' survival ranking at more than 50% of the sites visited. However, those with the highest survival recorded a '3' vigour ranking at only 34% of the sites, thus persistence was not necessarily dependant on vigorous growth. Seven genera (10 spp) recorded the highest vigour ranking (Table 5) and these remained productive even though the assessment was carried out in the latter part of a drought-affected growing season.

High vigour was recorded for various plants across the range of sites visited, so was not restricted to a narrowly defined environmental range despite the relatively dry summer conditions. For instance *T. medium* was recorded as high vigour and productivity at both ungrazed sites (Cockayne and Sievwright trials) and at a recently grazed site (Mt John). Results for *D. pentaphyllum* were similar. It had not been grazed for at least 2-3 months at Stony Ck, Earnsclough-Omeo or Bendigo, but was recently grazed at Otematata and Earnsclough-Shepherds Flat.

The majority of surveyed legumes (seven genera and 20 spp) recorded a moderate vigour (ranked '2'). High survival was noted at 20% of the sites, with 50% of them recording moderate survival for the species involved. *Trifolium* spp were predominant with seven species noted. Others included *Astragalus* (five spp), *Coronilla* (one spp), *Dorycnium* (two spp), *Lotus* (two spp), *Lupinus* (one spp) and *Medicago* (two spp).

Species with a vigour ranking of '1' included

Astragalus (four spp), *Coronilla* (one spp), *Dorycnium* (three spp), *Lotus* (two spp), *Medicago* (two spp), *Trifolium* (nine spp not including *T. arvense*) and *Vicia* (one spp).

Altitudinal influence

Sites covered a range of altitudes. In the sub-300 m 'semi-arid' zone, species with the best ranking were *D. hirsutum*, *D. pentaphyllum*, *M. alba* and *M. officinalis*. *Astragalus cicer*, *A. falcatus*, *A. glycyphyllos*, *A. mongolicus* and *L. corniculatus* also grew moderately well in this zone.

In the 300-500 m altitude drought-prone environments, 10 genera (17 spp) were recorded. The best rankings included *D. hirsutum* and *D. pentaphyllum*. *Astragalus cicer*, *L. corniculatus*, *M. sativa*, *T. ambiguum* and *T. medium* had moderately good rankings.

Legumes were well represented at most sites surveyed within the 'mid'-altitudinal band (500-800 m). Eight genera were present, with about 20 species. Those with best rankings included *A. falcatus*, *D. pentaphyllum*, *L. polyphyllus*, and *T. medium*. *Lotus corniculatus*, *Lupinus arborea*, *T. ambiguum*, *T. canescens*, *T. hybridum*, *T. pratense* and *T. repens* were moderately good.

At the higher altitude Glentanner sites (over 800 m) a total of five genera (11 spp) were found. Best species included *Lotus corniculatus* and *L. pedunculatus*, *Lupinus polyphyllus*, *T. ambiguum* and *T. medium*. Other legumes growing in that environment exhibited poor-medium vigour and/or survival.

Earnsclough sunny aspect accelerated screening trial

Although frost heave and stock ingress had affected all three plots at Earnsclough-Shepherds Flat, many of the original plantings were still evident. Cattle grazing was evident on *L. corniculatus* and *D. pentaphyllum*, but other species showed little, if any, recent foliage removal. *Lotus*, *Medicago* and *Dorycnium* were among the more palatable species at this site and, despite the recent grazing, generally recorded the greatest plant height.

The sunny aspect plot contained the greatest number of legume species, and of these, *C. varia*, *L. corniculatus*, *T. repens* and *T. pratense* had the highest number of plants per replicate (Table 6). Some were probably seedlings from the original plants.

Coronilla varia, *T. ambiguum* and *T. medium* plants appeared to be in original locations, but rhizomatous spread was considerable. *Astragalus glycyphyllos*, *D. pentaphyllum* and *T. canescens* plant plots were also readily re-locatable.

appeared to provide greater soil surface protection from potential erosion agents and therefore potential for revegetation. Remaining *Festuca novae-zelandiae* stands in the area have a low plant density but, even at just 1 plant/m², they provide average groundcover and greater biomass (Table 6), although

Table 6 Legume species survival and growth on the Earnsclough-Shepherds Flat sunny site after a decade. Mean plant number and Standard Error of Mean (SEM) per replicate (0.1 ha), mean area and height of plants, and percentage contribution to total plot ground cover are presented. Species are in descending order of ground cover.

Binomial	Plant # per rep (SEM)	Mean plant radius (mm)	Single plant area (m ²)	Ground cover (%/0.1 ha)	Mean Plant height (mm)	Fresh plant volume (m ³ /0.1 ha)
<i>Coronilla varia</i>	33 (3.8)	1100	3.8	12.6	30	3.8
<i>Trifolium medium</i>	11 (2.4)	1000	3.1	3.3	30	1.0
<i>T. ambiguum</i> 9	(0.6)	1100	3.8	3.2	20	0.7
<i>T. arvense</i> 20000 [‡]	20	0.00	2.5	60	1.5	
<i>T. repens</i>	50 (4.5)	300	0.3	1.4	20	0.3
<i>T. red</i> *	4 (1.4)	900	2.5	1.0	25	0.25
<i>Lotus corniculatus</i>	30 (2.4)	200	0.1	0.4	200	0.8
<i>T. canescens</i>	9 (0.4)	300	0.3	0.3	30	0.1
<i>Dorycnium pentaphyllum</i>	12 (2.4)	250	0.2	0.3	150	0.4
<i>T. pratense</i>	22 (4.0)	150	0.1	0.2	100	0.15
<i>Astragalus glycyphyllos</i>	3 (0.5)	250	0.2	0.1	50	0.03
<i>Lotus pedunculatus</i>	2 (0.9)	200	0.1	0.0	150	0.03
<i>T. fragiferum</i>	7 (0.6)	100	0.03	0.0	20	0.00
<i>Medicago sativa</i>	2 (0.5)	100	0.03	0.0	100	0.01
<i>Vicia sativa</i>	1 (0.5)	75	0.02	0.0	30	0.00
<i>Festuca novae-zelandiae</i> [¶]	1000	90	0.03	2.5	250	6.4

[‡] Dominant resident legume, numbers estimated.

* Unidentified rhizomatous red clover.

[¶] Comparative example based on typical local population of 1 plant per m².

Coronilla varia, *T. ambiguum* and *T. medium* had the greatest plant spread (Table 6) but, with a plant height of only 2-3 cm and sparse branching, ground cover during mid-summer was not comprehensive with much bare ground and litter apparent. Potentially, these plants also provided the greatest amount of fresh biomass per replicate, much of which should be acceptable to stock.

Dense, well-foliated plants of *A. glycyphyllos*, *D. pentaphyllum*, *T. canescens* and *T. fragiferum*, although of smaller spread and lower plant density,

the latter would typically be of low palatability.

Discussion

The primary objective of this survey was to determine which legume species survived and grew well over time at a range of hill country trial sites in the central South Island, particularly within drier environments and focussing on species not readily available commercially. In total, about 40% of the species assessed were established by drilling or oversowing, and the remainder by hand planting. Relating that to

survival, about 32% of species that recorded the highest survival ranking (all sites) were established from a direct seeded (drilled or oversown) source. The same was true for about 44% of species that recorded a moderate survival ranking and 36% of species that recorded a low survival ranking. Plants of *Dorycnium*, *Lotus*, *Lupinus* and *Trifolium* species that were established using both direct seeding and hand planting techniques at one or more sites were generally ranked closely for vigour thus, once in the ground, plants grew similarly.

In total, 28 species from 11 genera survived at one or more of the trial areas surveyed. For example, 14 clover species were originally planted at Earnsclough, of which six survived (Table 6). Based on the parameters assessed (survival, vigour and productivity), approximately about 30% of the total surviving plant species were above average in their ranking, several at environmentally disparate sites in both Central Otago and the Mackenzie Basin. The most successful species included *A. falcatus*, *C. varia*, *D. hirsutum* and *D. pentaphyllum*, *L. polyphyllum*, *M. alba* and *M. officinalis*, *T. canescens*, and *T. medium*.

Conversely, known establishment failures included 22 species from 11 genera (Table 4) and various reasons were identified for this. In many cases seed failed to germinate, either through poor viability or, more commonly, due to adverse environmental effects (drought, temperature) at, or shortly after, establishment. Of those legumes, certain species cannot be recommended for further investigation where the following environmental constraints apply: *D. rectum* (unseasonal cold temperatures), *D. suffruticosum* (drought), *H. coronarium* (cold temperatures and drought), *Lupinus* spp. (drought), *Onobrychis viciifolia* (drought), *Ononis pusilla* (drought). Failures that occurred with species like *A. cicer*, *Lotus* spp., *Medicago* spp., *Melilotus* spp., and several *Trifolium* spp. are more difficult to explain and probably involve factors such as poor establishment, environmental issues, plant maturity and possibly grazing management.

Medium-term revegetation and development for South Island dry country areas within low–moderate (250–550 m) altitude environments should be possible using legume selections from the successful species identified in the previous paragraph. For example, *Dorycnium* species retain forage over winter and can also provide low shelter during lambing if established in specialised forage banks (Wills *et al.* 1999). They

can be drilled and they reseed and survive well even on very dry, exposed sites, but lack of seed is a major drawback. *Astragalus*, *Coronilla* and *Trifolium* species (especially *T. medium*; Woodman *et al.* 1992) are probably best applied as a component of seed mixes when tussock grassland development is undertaken, but again, seed is not readily available. *Melilotus* is a good dryland nurse crop (Wills 1984) and *Lupinus* has potential for grassland sites receiving rainfall >550 mm (Scott *et al.* 1995); however, seed sources are lacking for both.

Reasons for the poor commercial uptake are diverse and not easy to specify. Establishment and management information relating to many of these legumes has been in the scientific and public arena for a number of years. Considerable interest is still shown by farmers in dryland forage and niche fodder crop development, at least in Central Otago and particularly during drought events. However, that interest remains small scale despite regular and ongoing promotion through field days, monitor farm/landcare groups, a Sustainable Farming Fund project and Otago Regional Council interest.

Few commercial companies have committed to serious involvement with these legumes, presumably for economic reasons, but their field officers do maintain an interest in them.

Coronilla varia, *D. hirsutum*, *L. polyphyllus* and *T. medium* are all considered to have potential for greater development and promotion to increase their availability and use. However, demand may not be large enough to attract investment by seed companies, particularly where site-specific cultivars are developed. Some, like *Dorycnium*, do have a small supporting market in the forestry industry and opportunities in the international market are a subject for further research.

Where included in the surveyed trials, commercially available ‘traditional’ legume species like *L. corniculatus*, *M. sativa*, *T. ambiguum*, *T. pratense* and *T. repens* exhibited good survival and average to good vigour and productivity, although some problems were noted in some cases with mature stands degenerating and dying out. Their use under land management systems with medium to high fertility and moisture levels (Scott 2001) in pastoral agricultural systems in New Zealand will continue.

Several of the legumes identified in this survey, including *A. falcatus*, *A. mongolicus* and *A. cicer*, *D.*

pentaphyllum, *M. alba* and *M. officinalis* and *T. canescens*, show promise in small scale trials but need further evaluation to establish their full potential and most suitable agro-pastoral role. Development of small-scale seed production is needed to better define best site, management and use characteristics for them, and to explore possibilities for commercial production.

This survey did not attempt to review in detail all legume species that have been assessed in previous trials at all times of the growing season. Some of that work is still being documented (Scott *et al.* in preparation). However, most trials were evaluated after environmental, fertility and management conditions had long since reverted to levels consistent with 'normal' farming practice. Much is already known about the management of the persistent legumes discussed here and basic information is readily available to farmers (MRDC 1992, AgResearch 1995). With the exception of the few non-grazed plots included in this survey, grazing management was too variable to comment on with any confidence, other than to say most trials had been grazed on a similar basis to surrounding paddocks for a number of years. The objective was to identify legume persistence after an extended period of reasonably conventional grazing management and, by then applying existing management knowledge if and when these plants are used, there is a good chance they may be successfully utilised under practical farming situations.

The information collected on plant survival and growth during what was a yet another very dry growing season is a valuable indicator of those legume species with potential to help revegetate or develop dryland farming areas not ideally suited to improvement with commercial seed varieties. However, as only small quantities of seed are available, farmers are advised to keep in close contact with the equally scarce, surviving researchers to maximise opportunities for dryland legume development utilising these species.

ACKNOWLEDGEMENTS

We thank runholders in Central Otago and the Mackenzie Basin for their co-operation, AgResearch staff for assisting with text reviewing and R. Littlejohn for assistance with data analysis.

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