

THE COCKAYNE PLOTS OF CENTRAL OTAGO - A 1985 EVALUATION

Summary: The 'regrassing' trials established by L. Cockayne in 1920 on Northburn Station, near Cromwell, Central Otago, were last described by Douglas (1970) from observations made in 1967. In this paper, the early results are briefly reviewed and discussed in comparison to a 1984/85 assessment of the plots.

This assessment includes quantitative data on the composition and spread of both pasture species and tree species inside and outside each trial area, thus establishing a base for future appraisals of Cockayne's plots.

The ability of several plant species to survive and spread from the plots, despite the semi-arid climate and soils of low fertility, is noted in relation to possible low-cost development in depleted tussock grasslands. The spread of conifers from the Cockayne plots is viewed with concern.

Keywords: L. Cockayne, Northburn Station, montane tussock grasslands, soil conservation, exclosure plots, revegetation, regrassing trials, sheep's burnet, yarrow, Chewings fescue, danthonia, zig-zag clover, tall oat grass, conifers.

Introduction

In the high country of New Zealand and especially the Central Otago region there has long been an interest in the selection of new plants, initially to provide forage for stock (Wilkin, 1877) and later for revegetation of dry depleted grassland (Macpherson, 1913; Cockayne, 1919-1922; Sewell, 1922; Sievwright, 1956).

Central Otago is in a semi-arid climate zone where the lower-altitude (150-400 m asl) areas have a rainfall of only 300-450 mm/annum (New Zealand Meteorological Service Rainfall Observations, 1984). The lack of rainfall is a problem made worse by seasonal dry north-westerly winds, particularly on sunny aspects. The benefits of moisture-laden southerly winds are lessened by the rain shadow effect of the high, block-faulted schist mountains which surround Central Otago's extensive intermontane basins.

Degradation of soil and vegetation condition followed European settlement of Central Otago. Mather (1982) considered that in areas subject to severe climate fluctuations this process, which he termed desertification, was facilitated by the prevailing system of land tenure, the high rabbit population and the indiscriminate use of fire.

Although many early reports were written on the depletion of the South Island's tussock grasslands (Macpherson, 1910; Petrie, 1912; Cockayne, 1919b, 1922; McCulloch, 1917), implementation of change to prevent further degradation ~as slow. Macpherson and Cockayne proceeded with their revegetation work, a full description of which is given by Macpherson (1910a, 1911, 1912, 1912a) and Cockayne (1919 *et seq.*,

see Thompson, 1982). These early trials have subsequently been re-examined by several investigators (McGillivray, 1929; Tennent, 1935; Zotov, 1938; Calder, 1944; Lunn, 1951; Douglas, 1966, 1970).

With increased subdivision and stocking pressure on Northburn Station and the deterioration of several plot fences, a re-evaluation of the Cockayne trials has become important. The performance of sheep's burnet for semi-arid revegetation (Wills, 1983) and its persistence in the Cockayne trials, and the spread of exotic conifers on South Island rangelands (Hunter and Douglas, 1984), are of interest particularly as plant composition in the plots is likely to alter with applications of fertiliser and seed in future oversowing programmes.

The Cockayne Trials

The trial areas (Fig. 1) were established in 1920 on Northburn Station on the west side of the Dunstan Ranges and covered an altitudinal range from about 900 ft (275 m) to 2600 ft (790 m) above sea level (Cockayne, 1922a). The chief objectives of the trials are summarised in Tennent (1935).

Twelve plots were located on differing aspects and were fenced to exclude stock and rabbits. Each plot was one quarter to one half acre (0.1 - 0.2 ha) in area and subdivided into three treatments:

- (a) autumn sowing, or
- (b) spring sowing of grasses, clovers and herbs, and
- (c) a pasture species selection trial.

Seed of many different plants (Appendix I) was broadcast, or broadcast then raked (to simulate harrowing), both inside and outside the plots in May and September 1920 and March 1921. An additional plot (No. 13) was fenced and sown in September

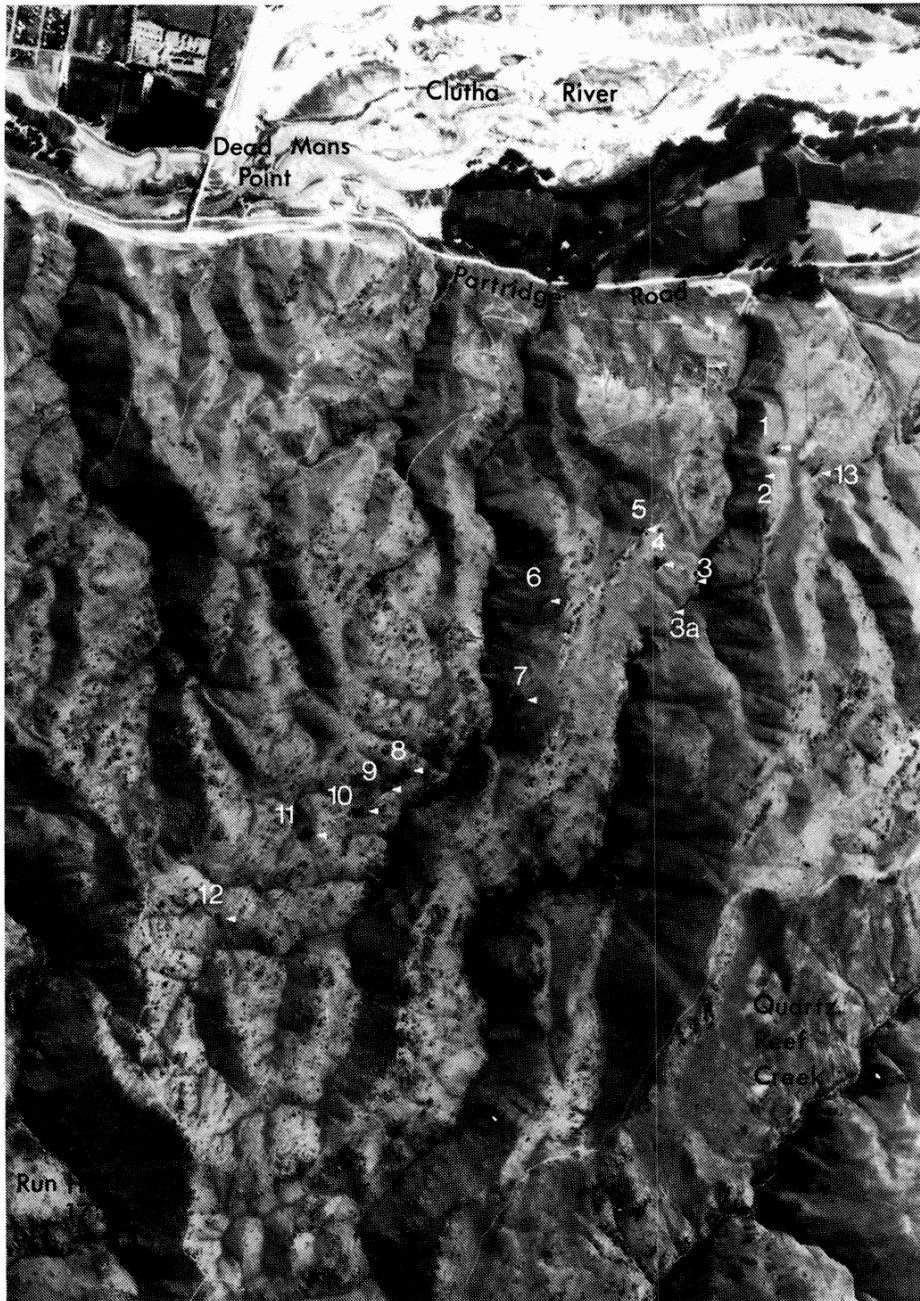


Figure 1: Cockayne plots on foothills of Dunstan Range between Cromwell and Lowburn. Plot 1 (275 m altitude) NZMS 1 S133 048728, Plot 12 (770 m altitude) NZMS 1 S133 057704. (Photo courtesy of Lands & Survey Department, Survey 8180, Run H/11, 17/2/83, scale 1:15000).

1920/March 1921 to ascertain the effects of harrowing and sheep trampling on plant establishment.

A detailed report on the condition of the trials was made by Tennent (1935). Stock were then allowed to graze the plots until 1936 after which only limited winter grazing was carried out. In 1948, fences were removed from plots 1 and 3 while plots 3A and 4 were fenced and oversown with an amended seed mixture (Appendix I). At this time zig zag clover (*Trifolium medium* L.) was transplanted from a few surviving plants throughout plot 5 and subsequently to other plots. Oversowing was carried out in plots 6, 7, 8 and 11 using lucerne (*Medicago sativa* L.) and crested wheat grass (*Agropyron cristatum* (L.) Gaertn.).

Reports to 1967

The species which established the best (Cockayne, 1922b) were lucerne, cocksfoot (*Dactylis glomerata* L.), tall fescue (*Festuca arundinacea* Schreb.), Chewings fescue (*Festuca nigricans* Lam. Healy, 1984), yarrow (*Achillea millefolium* L.) and chicory (*Cichorium intybus* L.).

Perennial ryegrass (*Lolium perenne* L.), sheep's burnet (*Sanguisorba minor* Scop.) and subterranean clover (*Trifolium subterraneum* L.) had moderate establishment while all other species performed poorly. Spelling from grazing was considered an ineffective method for regressing except at higher altitudes where live tussocks were present initially (Cockayne, 1922a). Broadcasting and raking in seed were successful on both sunny and shady aspects, late autumn sowing being better on sunny slopes and early spring sowing better on shaded slopes. Establishment was best on the deep soils of the shady and semi-shady aspects and improved with altitude.

Tennent (1935) also concluded that spelling was largely ineffectual in promoting revegetation, particularly on sunny faces, unless native grasses were present. Seed sowing (broadcast, harrowed and sheep-trampled) was effective providing at least eighteen months was allowed for plant establishment. Sheep-trampling and harrowing were the best treatments for oversowing on to sunny slopes. So wings made outside the plots established successfully but largely had been eaten by May 1921.

After two and a half years grazing (June 1930 to December 1932) Tennent noted that, given 'rational treatment', it should be possible to maintain the palatable species as pasture.

Lunn (1951) noted that, in 1936, the outstanding feature of the plots was the growth of tall oat grass (*Arrhenatherum elatius* (L.) Beauv.), yarrow and browntop (*Agrostis capillaris* L.). A decade later the

following were described as making good growth: zig zag clover; Kentucky bluegrass (*Poa pratensis* L.); Chewings fescue; tall oat grass; sheep's burnet; yarrow; with some cocks foot and lucerne. In 1950 the most promising species were tall oat grass (predominantly on shady slopes) and sweet vernal (*Anthoxanthum odoratum* L.), cocksfoot, Chewings fescue, yarrow and sheep's burnet.

In a summary of the plots, Lunn (1951) noted:

- (a) The suppression but not replacement of other species by tall oat grass on shady faces.
- (b) The excellent ground cover produced by a Kentucky bluegrass/yarrow association.
- (c) The good performance of sheep's burnet on sunny faces and winter greenness of Chewings fescue.

Douglas (1970) indicated that the prolonged and severe grazing during the 1930's resulted in a change from upright palatable species to rhizomatous or stoloniferous, less palatable species. Although little information was given regarding the extent of the various plants, tall oat grass, Chewings fescue, Kentucky bluegrass and yarrow were described as dominant, but increases of lucerne, cocksfoot and sheep's burnet were also noted. Tall oat grass had spread at least 400 m from some plots, but remained largely ungrazed. Most other species had spread little outside the plots.

Information was also presented on the regeneration of tree species, pines and eucalypts (Appendix II), planted by Cockayne. Seedling establishment of the trees outside the plots was restricted to rocky outcrops inaccessible to stock.

It is notable that there has been little documentation of grazing management since the 1930's and a slow deterioration of the fences during this time with rabbits, and in some cases sheep, gaining access to the plots.

Methods

The current assessment of the plots, conducted in January and March 1984 and January 1985, included the status of fences, the flora and ground cover of introduced oversown pasture species and naturalised plants (Tables 1 and 2), and the regeneration of trees (Tables 3 and 4). Photographic records were made of all plots, where possible from viewpoints identical to those in early papers.

In each plot the % pasture ground cover per plot was visually estimated. The composition of the pasture vegetation was then determined using 1 m² quadrats, 12 per plot except where trees substantially reduced

the pasture area (Tables 1 and 2). Also, the contribution of the main pasture species to standing biomass within the quadrats was ranked on a 1-5 scale (1 = highest contribution). Outside the plots, 1 m² quadrats were placed at regular intervals along lines 1 m and 10 m from each boundary. The number of quadrats around Plot 5 was reduced because of cultivation along part of its perimeter (see Table 2). Beyond 10 m from the plots few of the trial species were evident and, for those present, the maximum distance from the boundary and the approximate direction of spread was determined.

For the pines and eucalypts, both inside and outside the plots, numbers of trees in each of seven diameter breast-height categories were recorded (see Tables 3 and 4). The predominant *Pinus* or *Eucalyptus* species occurring in and around each plot was also noted.

Soil tests were carried out on the intact plots in June 1986.

Results

a) *The pasture species*

The vegetative composition and standing biomass at time of assessment are given in Tables 1 and 2. Other features noted for the plots are listed below (refer also to Figures 2a-3f).

- Plot 1 (Fig. 2a); Aspect sunny, north westerly. Open since 1948, no fencing remains, now in dryland lucerne. The two radiata pines on the left of Fig. 2a are in this plot.
- Plot 2 (Fig. 2b); Aspect shady, southerly. Fence intact and rabbit-proof, pasture species dominate, especially tall oat grass which has also spread considerably outside the plot.
- Plot 3 Aspect sunny, northerly. Open since 1948, no fencing remains, has reverted to hares foot trefoil, vipers bugloss.
- Plot 3a (Fig. 3a); Aspect sunny, northerly. Established 1948, fence is stock-proof but rabbits have access to this plot which is dominated by cocksfoot.
- Plot 4 (Fig. 3b); Aspect sunny, northerly. Fence is stock-proof but not rabbit-proof. About half the plot is in pasture (Kentucky bluegrass and sheep's burnet), the remainder being under snow gums which have coppiced (compare Fig. 2 of Douglas, 1970 with Fig. 2 of Cockayne 1922a).

- Plot 5 (Fig. 2c); Aspect sunny, westerly. Fence is stock-proof but not rabbit-proof, most of plot is in pasture, particularly sheep's burnet. Trees have multiplied since 1967 (compare Fig. 2c with Figs. 3,4 of Douglas, 1970).
- Plot 6 (Fig. 2d); Aspect shady, southerly. Fence no longer stock-proof. Ground cover is dominated by tall oat grass which is also widespread outside the plot.
- Plot 7 (Fig. 2e); Aspect shady, southerly. Fence intact and rabbit-proof. Ground cover is dominated by Chewings fescue and tall oat grass which is also widespread outside the plot, particularly to the east where it is present up to 1000 m from the fence.
- Plot 8 (Fig. 3c); Aspect sunny, northerly. Fence stock-proof but not rabbit-proof. About half of the area now occupied by trees and the main pasture species is danthonia.
- Plot 9 (Figs. 2f, 3d); Aspect shady, south-westerly. Fence not stock-proof, approximately one-third of area occupied by trees with danthonia and sheep's burnet dominating the pasture ground cover.
- Plot 10 (Fig. 2f); Aspect partly shady, westerly ridge. Fence not stock-proof and plot ground cover completely dominated by trees. Trees have spread between plots 9 and 10 (compare Figs. 5 and 6 of Douglas, 1970).
- Plot 11 (Fig. 3e); Aspect shady, south westerly. Fence is stock-proof but rabbits have access to the plot. Ground cover is about two-thirds pasture and dominated by Chewings fescue.
- Plot 12 (Fig. 3f); Aspect partly shady, westerly ridge. Fence is completely rabbit and stock-proof. Ground cover is all pasture and is dominated by Chewings fescue.
- Plot 13 (Fig. 2a); Aspect sunny, north-westerly. Now extended and subdivided into a stockholding yard with pasture cover modified by this.

Within the three plots which remain completely rabbit-proof (2, 7 and 12) pasture species dominate the ground cover and grasses form a major part of the standing biomass, in particular tall oat grass and Chewings fescue, along with yarrow.

Plots that are open to rabbits only (3a, 4, 5, 8 and 11) have similar pasture ground cover to those in which stock also have access (6, 9). However, some of the rabbit-only plots do have larger areas of rank

Table 1: Vegetation composition of Cockayne trials, Northburn Station - shady aspect plots. Quadrats are: A, within the plot; B, 1 m outside; C, 10 m outside; † other species sown or planted were not recorded, or have extremely limited distribution; ✓ species recorded present in quadrat; * number of quadrats in which species is in top five rankings for standing biomass; + number of quadrats in which species is ranked top for standing biomass.

Plot No.	2			6			7			9			10			11			12				
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C		
<i>% pasture ground cover per plot</i>																							
	100			75			95			65			0			65			100				
<i>Mean % ground cover per quadrat</i>																							
Bare ground/Rock	8	21	23	21	25	31	0	16	11	19	34	30	69	32	19	36	32	3	35	41			
Litter	13	11	17	26	20	11	20	5	21	18	17	13	19	10	38	19	8	7	8	13			
Vegetation	79	68	60	53	55	58	80	79	68	63	49	57	12	58	43	45	60	90	57	46			
<i>Mean % ground cover of species sown or planted per quadrat †</i>																							
Yarrow	13	✓		1	✓		1			1	✓	2		✓	9	14	14	14	15	13			
Blue wheat grass	3	✓	4											✓									
Sweet vernal										4	3	4		8		2	3						
Tall oat grass	33	13	24	23	24	25	36	10	19	3	2	✓	✓	3	11	2	2	17	✓				
Browntop									2		2												
Cocksfoot							3											3		✓			
Chewings fescue	10	5	✓	17	2	7	29	40	30	9	3	3		1	8	17	14	23	40	25	7		
Catsear	3	✓	✓	✓	✓	✓	✓	2	✓	✓	1	✓		✓	✓	✓	✓	✓	✓	✓	✓		
Blue tussock	9	✓									1	✓		2				✓	✓	✓	3		
Kentucky bluegrass	3	4		3	9	✓	9	✓		4	✓	✓						✓	✓	1	3		
Danthonia										20	13	35		6	11			✓	✓	✓	✓		
Sheep's burnet			✓							16	7	5						✓	✓	✓	✓		
Zig zag clover																			10				
<i>Mean % ground cover of minor species per quadrat</i>																							
Silvery hairgrass		3	✓	✓	1	1		3	✓					2	✓	4	4	✓	4	2			
Soft brome		✓	✓	✓				✓										✓	✓	✓			
Downy brome		10	5	✓	1	3					3	✓				2	1	✓	✓	8			
Mouse ear chickweed	2		3	✓	✓	✓	✓	✓	1					✓	✓	✓	✓	✓	✓	✓			
Hawksbeard	✓	1	2	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓			
Viper's bugloss	✓	3	5	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓			
Small erythranthera		✓		✓						✓	1	1		1	2			✓	✓	5	1		
Hard tussock											2	1		5			3	✓	✓	6			
Scabweed		1	3	✓		1		1	2	✓	3	2		2	11		3	✓	2	1			
Sheep's sorrel	✓	1	2	✓	1	✓	✓	✓	✓	✓	✓	✓		✓	✓		✓	✓	✓	2			
Haresfoot trefoil	1	24	12	8	14	18	✓	16	16	1	10	6		✓	7		6	4	✓	1	✓		
Vulpia hairgrass		✓		✓	1	3		1	1		✓	✓		✓	✓	✓	✓	✓	✓	✓			
<i>Quadrat ranking of sown species for standing biomass</i>																							
Yarrow	4(1)			2(0)	1(0)		1(0)			2(0)	2(0)	3(0)						5(1)	11(5)	10(1)	11(0)	14(4)	12(0)
Blue wheat grass	3(0)			3(1)																			
Sweet vernal										3(0)	2(1)	3(1)		3(2)		2(0)	2(1)						
Tall oat grass	10(6)	7(3)	7(7)	11(6)	11(9)	10(7)	12(6)	9(1)	12(1)	3(0)	3(0)	1(0)		4(1)	7(3)	4(0)	2(1)	12(1)	3(0)				
Browntop																							
Cocksfoot							2(0)											1(0)			3(0)		
Chewings fescue	7(2)	8(0)	1(0)	11(5)	6(1)	4(2)	11(6)	13(11)	12(10)	6(2)	4(0)	4(0)		3(0)	5(2)	7(2)	11(6)	9(7)	12(9)	14(8)	6(3)		
Catsear	3(0)		1(0)	2(0)			1(0)	3(0)	5(0)	2(0)	3(0)						1(0)	1(0)		4(0)	1(0)		
Blue tussock	4(2)										1(1)				3(0)			1(0)	1(0)		7(0)		
Kentucky bluegrass	3(0)	2(1)		6(0)	6(2)	1(0)	5(0)			6(0)								1(0)	3(0)	2(0)	2(0)		
Danthonia										11(4)	9(6)	11(11)		9(7)	9(1)								
Sheep's burnet										10(6)	7(1)	10(0)									1(0)		
Zig zag clover																					2(2)		
<i>Number of quadrats</i>																							
	12	14	12	12	14	12	12	14	12	12	14	12	0	14	12	9	14	12	12	14	12		

Plot comprised of 100% tree species and associated litter

Table 2: Vegetation composition of Cockayne Trials, Northburn Station - sunny aspect plots. Quadrats are: A, within the plot; B, 1 m outside; C, 10 m outside; ‡ other species sown or planted were not recorded, or have extremely limited distribution; ✓ species recorded present in quadrat; * number of quadrats in which species is in top five rankings for standing biomass; + number of quadrats in which species is ranked top for standing biomass.

Plot No.	3			3A			4			5			8		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
<i>% Pasture ground cover per plot</i>															
	95			100			50			70			50		
<i>Mean % ground cover per quadrat</i>															
Bare ground/Rock	65	53	45	50	79	68	17	88	66	27	52	56	21	29	28
Litter	10	14	14	17	5	6	39	3	10	14	11	12	47	30	9
Vegetation	25	33	41	33	16	26	44	9	24	59	37	32	32	41	63
<i>Mean % ground cover of species sown or planted per quadrat‡</i>															
Yarrow													✓	✓	3
Blue wheat grass				1	✓			✓		✓					
Sweet vernal											✓			1	✓
Tall oat grass				3		✓							✓		3
Browntop															2
Cocksfoot				13		✓	1				✓				
Chewings fescue				3			1			8	3		6	9	5
Catsear	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	2
Blue tussock										✓	✓	2			
Kentucky bluegrass			4	✓			18			13	✓	✓			1
Danthonia	3	9	3	✓	3		7			3	6	✓	22	21	30
Sheep's burnet							15	4	4	30	✓	✓	1	3	3
Zig zag clover										3	✓				
<i>Mean % ground cover of minor species per quadrat</i>															
Silvery hairgrass											✓	✓	✓	✓	✓
Soft brome			✓								✓	✓	✓	✓	✓
Downy brome	4	3	3	2	1	1		✓	✓		✓	3	1	✓	✓
Mouse ear chickweed	✓	✓	1	✓		✓						1	✓	✓	✓
Hawksbeard	1	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	1	✓	✓
Viper's bugloss	7	9	10	6	3	11		✓	4		3	7			1
Small erythranthera	1	✓	2	✓	✓	✓		✓	✓		4	3	1	✓	3
Hard tussock	1		1											1	3
Scabweed			✓			1		✓	4		3	2		2	3
Sheep's sorrel				✓	✓	✓		2	✓		✓	✓		✓	1
Haresfoot trefoil	7	11	15	5	9	12	1	6	15	✓	18	14	1	3	5
Vulpia hairgrass		✓	✓	✓	✓	✓	✓	✓	✓		1	✓			1
<i>Quadrat ranking of sown species for standing biomass</i>															
Yarrow														1(0)	3(0)
Blue wheat grass				3(0)						1(0)					
Sweet vernal															1(0)
Tall oat grass				4(1)		2(0)									4(0)
Browntop															3(0)
Cocksfoot				11(9)		2(0)	1(0)				2(0)				
Chewings fescue				4(0)			1(0)			5(1)	2(0)		4(1)	5(3)	6(0)
Catsear					1(0)						1(0)	2(0)			3(0)
Blue tussock											1(0)	2(0)			
Kentucky bluegrass	*+		3(2)	1(0)			7(3)			7(2)					2(0)
Danthonia	5(1)	11(4)	7(1)		2(2)		7(2)			3(0)	3(2)		6(5)	12(7)	11(10)
Sheep's burnet							6(4)	8(1)	9(0)	11(9)			3(0)	6(1)	5(0)
Zig zag clover										3(0)					
<i>Number of quadrats</i>	12	14	12	12	14	12	9	14	12	12	10	10	9	14	12

Table 3: Numbers and size distributions of pines on the Cockayne Plots, Northburn Station, 1984. # plots 2 & 12 contain no trees; ° total A, 1967 data (Douglas, 1970), total B, 1984 data (present study); * not stated in Douglas 1970; + totals for plots 9 and 10 summed; ¶, given in descending order of numerical predominance. Plot 6 contains 1 dead pine >49 cm dbh.

Plot #	Diameter at Breast Height (cm)							Total °		Predominant Species ¶
	<5	5-9	10-19	20-29	30-39	40-49	>49	A (1967)	B (1984)	
1 Inside	-	-	-	-	-	-	2	?*	3	<i>P. radiata</i>
1 Outside	-	-	-	-	-	-	-	?	0	-
3 Inside	-	-	-	-	-	1	1	?	2	<i>P. ponderosa</i>
3 Outside	2	-	-	-	-	-	-	?	2	<i>P. ponderosa</i>
3A Inside	1	-	-	1	-	-	-	?	2	<i>P. ponderosa</i>
3A Outside	-	-	-	-	-	-	-	?	0	-
5 Inside	2	9	14	1	-	1	-	21	27	<i>P. ponderosa, P. nigra</i>
5 Outside	-	-	-	-	-	-	-	?	0	-
6 Inside	2	-	-	-	1	-	1	2	4	<i>P. nigra</i>
6 Outside	-	-	-	-	-	-	-	?	0	-
8 Inside	38	8	7	6	4	2	5	26	69	<i>P. ponderosa = P. nigra, P. radiata</i>
8 Outside	20	3	-	-	1	-	-	?	24	<i>P. ponderosa = P. nigra</i>
9 Inside	4	3	4	3	2	3	5	12	24	<i>P. nigra, P. ponderosa, P. radiata</i>
9 Outside +	643	131	27	6	-	-	-	?	807	<i>P. nigra = P. ponderosa</i>
10 Inside	78	57	117	7	2	3	-	165	264	<i>P. ponderosa, P. nigra</i>
10 Outside +	See plot 9 above									
11 Inside	17	14	11	10	2	-	2	25	42	<i>P. nigra</i>
11 Outside	15	1	-	-	-	-	-	?	16	<i>P. nigra</i>
13 Inside	-	-	4	2	3	3	2	?	14	<i>P. radiata</i>
13 Outside	6	-	-	-	-	-	-	?	6	<i>P. radiata</i>

Table 4: Numbers and size distributions of eucalypts on the Cockayne Plots, Northburn Station, 1984. # plots 2 & 12 contain no trees, plots 4-10 have no eucalypts outside; ° total A, 1967 data (Douglas, 1970), total B, 1984 data (present study); * not stated in Douglas 1970; ¶, given in descending order of numerical predominance. Plot 3, 8 and 10 each contain 1 dead eucalypt >49 cm dbh.

Plot #	Diameter at Breast Height (cm)							Total °		Predominant Species ¶
	<5	5-9	10-19	20-29	30-39	40-49	>49	A (1967)	B (1984)	
3 Inside	-	-	-	-	-	-	1	1	1	<i>E. coccifera</i>
3 Outside	2	-	-	-	-	-	-	?*	2	<i>E. gunnii</i>
4 Inside	15	18	9	4	1	-	1	39	48	<i>E. coccifera</i>
5 Inside	6	2	2	1	1	1	-	2	13	<i>E. coccifera</i>
6 Inside	23	-	-	-	-	1	1	2	25	<i>E. gunnii, E. coccifera</i>
7 Inside	-	-	-	-	-	-	1	?	1	<i>E. coccifera</i>
8 Inside	14	-	-	-	-	-	-	4	14	<i>E. gunnii</i>
9 Inside	-	-	-	-	-	-	4	?	4	<i>E. coccifera</i>
10 Inside	6	-	-	-	-	-	-	?	6	<i>E. gunnii</i>



Figure 2: a) Plots 1, 2 and 13 (Apr. 1985) showing the nature of the country and the proximity of plots to Northburn Station homestead. The two radiata pines on the left are in Plot 1, those partly obscured by the ridge are in Plot 13.

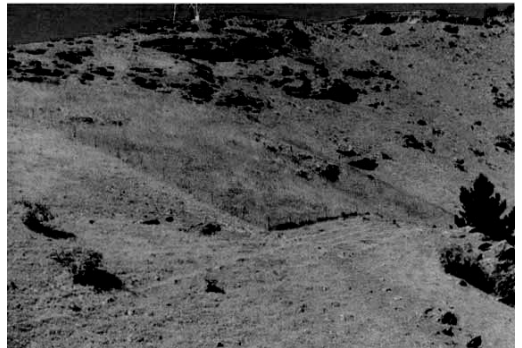


Figure 2: b) Plot 2 (Jan. 1984) dominated by tall oat grass which has spread to the open ground east of the plot.



Figure 2: c) Plot 5 (Jan. 1984) dominated by sheep's burnet, with pines and eucalypts.



Figure 2: d) Plot 6 (Apr. 1985) dominated by tall oat grass. Note spread of oat grass and exclusion of native tussocks. Corsican pines now number 4 (plus one dead) and there are 24 cider gums and 1 snow gum present (compare Fig. 4 of Cockayne, 1922a).



Figure 2: e) Plot 7 (Jan. 1984) dominated by tall oat grass and Chewings fescue with the former spreading vigorously to the south and east. A single snow gum is present.



Figure 2: f) Plots 9 and 10 (Apr. 1985). Plot 10 (on ridge in background) is now completely dominated by ponderosa and Corsican pines with numerous seedlings of both species outside. Six seedling cider gums present. Note pine spread between plots 9 and 10 (compare Figs. 5 and 6 of Douglas, 1970).

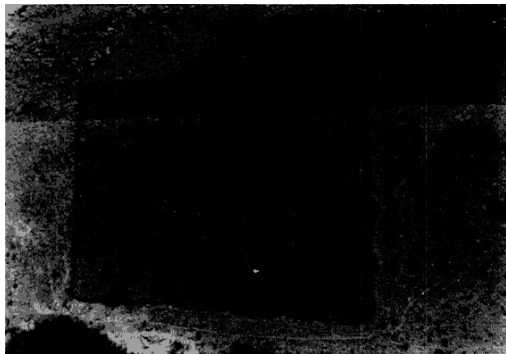


Figure 3: a) Plot 3A (Jan. 1984) dominated by tall oat grass with one ponderosa pine and seedling.



Figure 3: b) Plot 4 (Jan. 1984) dominated by sheep's burnet and Kentucky bluegrass. Snow gums have coppiced vigorously (compare Fig. 2 of Douglas, 1970 and Fig. 2 of Cockayne, 1922a).



Figure 3: c) Plot 8 (Jan. 1984) dominated by danthonia, with ponderosa and Corsican pines and cider gums. The Corsican pines and the cider gums are heavily browsed by possums (compare Fig. 3 of Cockayne, 1922b).

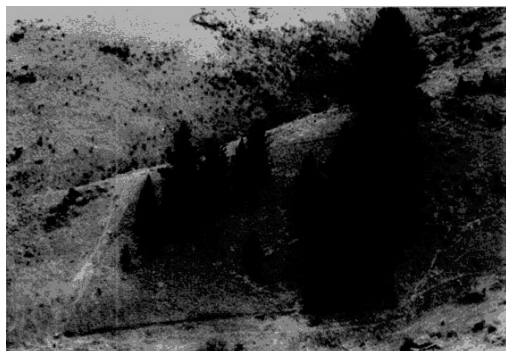


Figure 3: d) Plot 9 (April 1985). Dominant pasture species include sheep's burnet and danthonia, with pines (Corsican, ponderosa and radiata) and snow gums. Pines are spreading vigorously to east of plot.

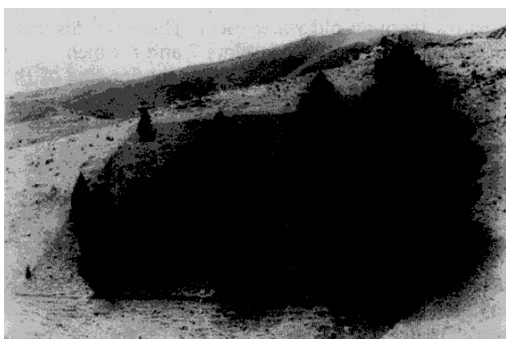


Figure 3: e) Plot 11 (Apr. 1985) with Corsican pines, tall oat grass and Chewings fescue as dominant pasture species. No eucalypts are present (compare Figs. 7 and 7 of Douglas, 1970),



Figure 3: f) Plot 12 (Jan. 1984) dominated by Chewings fescue. Some native tussocks are present and also tussock hawkweed (compare Figs. 1 and 2 of Cockayne, 1922b).

grass (mainly tall oat grass) less heavily grazed than much of the Chewing fescue and sheep's burnet.

A comparison of the assessment by Tennent (1935) with those of Lunn (1951), Douglas (1970) and the present study shows some interesting floristic changes with time on the sunny and shady aspect trials. In the sunny aspect plots (1, 3, 3a, 4, 5, 8 and 13) Tennent (1935) noted lucerne, cocksfoot, tall fescue, Chewings fescue and sheep's burnet as the dominant plants. Lunn (1951) reported that (in 1950) sheep's burnet and the native *Poa colensoi* were growing particularly well on sunny sites and Chewings fescue and cocksfoot were still prominent. Douglas (1970) did not distinguish between sunny and shady aspects but indicated that, of the plants above, Chewings fescue remained dominant and that lucerne, cocksfoot and sheep's burnet had increased. The present study shows that sheep's burnet, Kentucky bluegrass and Chewings fescue are now dominant on many of the sunny aspect plots including those open to grazing animals. Cocks foot, lucerne, tall oat grass and zig zag clover contribute little to the pasture cover of these plots.

On the shady aspect plots (2, 6, 7, 9, 10, 11 and 12) Tennent (1935) recorded a great variety of oversown trial species. Prominent among these were lucerne, cocksfoot, tall oat grass, Chewings fescue, browntop, yarrow and sheep's burnet. Lunn (1951) observed that tall oat grass was dominant on most shady face plots, although Kentucky bluegrass, yarrow, Chewings fescue and cocks foot were also present. As previously noted, Douglas (1970) was not specific regarding aspect but, of the above species, he recorded lucerne, cocksfoot, tall oat grass, Chewings fescue, Kentucky bluegrass and yarrow as being successful. The following plants are now dominant in the remaining shady aspect plots: tall oat grass; Chewings fescue; Kentucky bluegrass; yarrow. Small quantities of lucerne, cocksfoot, sheep's burnet, browntop, sweet vernal and zig zag clover are also found in these plots.

b) *The tree species*

The eucalypts, *Eucalyptus coccifera* and *E. gunnii*, and the pines, *Pinus nigra*, *P. ponderosa* and *P. radiata*, were established in the plots both from seed and by transplanting seedlings (Cockayne,

1922a-1922b). Regeneration has been prolific in the upper altitude plots and is most advanced in plot 10. According to Tennent (1935) this plot was opened to grazing at an early stage and remained in a depleted state. Lack of vegetation cover has apparently encouraged development of pine seedlings within the plot. However, outside plots 9 and 10, seedlings are prolific on the shady aspects (where vegetation cover is better) and amongst rock outcrops. These niches apparently provide sufficient seedling protection from browsing. Such tree establishment in unimproved high country grassland has occurred at several localities in New Zealand (Benecke, 1967; Hunter and Douglas, 1984).

Number and size distributions of trees (diameters at breast height) are presented in Tables 3 and 4. In spite of periodic browsing in and around most plots, the number of trees has substantially increased, particularly in plots 8 to 11. In these plots there are a large number of pine seedlings which, when cored, showed an age range of 20-30 years with coning beginning at about year 25 (N. Ledgard, NZFS, pers. comm., 1986). *P. nigra* and *P. ponderosa* have spread extensively and the source of seedlings outside plots 9 and 10 is now difficult to distinguish. These seedlings, many of which are from 12-14 years old, have spread to 250 m from the plots, mainly in a south and east direction along the prevailing north-westerly wind. Both *E. gunnii* and *P. nigra* are being severely browsed by possums, particularly inside the plots.

c) *Soil tests*

Soil pH readings (Table 5) show slight acidification in the higher plots (2 has dense moribund vegetation; 3a overflow from an old water race). There is a distinct change in Olsen P between plots 7 and 8 which corresponds with sulphurised super topdressing of the top plots in 1984. Only minor variations occur between plots with the other nutrients tested (Table 5).

Discussion and Conclusions

While improved establishment methods and management systems now allow increased pastoral utilisation in the high country grassland, recent information gained from the Cockayne trials is still very relevant. The persistence of plants of several species under conditions of continual browsing, harsh climate and low fertility indicates that these species may have a role in low cost revegetation on drought prone soils.

It is evident that plants requiring high fertility are seriously disadvantaged in these soils and that there

*Note: Samples of *E. coccifera*, identified as such by Douglas (1970), have subsequently been identified by D.S.I.R. as *E. ovata* Labill. (W.R. Sykes pers. comm., 1986).

Table 5: Soil test results. *Samples taken under pine trees.

Plot No.	pH	Calcium	MAF Quick Test Units			parts per million	
			Magnesium	Potassium	Sodium	Olsen-Phosphate	Sulphate Sulphur
2	6.2	12.0	22.0	6.7	1.6	4.0	7.0
3a	7.6	13.0	15.0	9.1	1.1	6.0	7.0
4	6.5	8.3	19.0	7.8	2.1	9.5	10.0
5	6.5	8.6	17.0	5.4	1.9	8.5	7.0
6	6.4	11.0	19.0	7.6	1.7	4.5	7.0
7	6.4	11.0	19.0	7.7	1.5	6.5	8.0
8	6.6	10.0	20.0	10.0	1.8	16.0	10.0
9	6.6	11.0	21.0	8.9	1.7	12.0	10.0
10*	6.3	11.0	20.0	10.0	1.9	27.0	10.0
11*	6.2	11.0	27.0	12.0	3.3	22.0	11.0
11	6.2	9.5	23.0	8.4	2.0	14.0	6.0
12	6.2	10.0	23.0	7.6	2.0	13.0	7.0

are distinct differences in vegetation which correlate with aspect. Douglas (1970) noted the constraint placed on legume species in Central Otago soils due to the lack of sulphur. If present knowledge regarding fertilisers (Sinclair and McIntosh, 1983) had been applied when the plots were established, this would have had a profound effect on the response of the pasture plants present. Lucerne, cocksfoot, red and white clover and 'Maku' lotus now find widespread use in both cultivated and oversown situations providing fertiliser levels are adequate (Ludecke, 1962; Cossens, 1983). However, problems still exist in revegetating drought-susceptible brown-grey and yellow-grey earth soils (McCaskill, 1973) and these relate mainly to establishment techniques and stock management.

The Cockayne trials, while not conveying a true picture of their potential agricultural value since they were overgrazed in the 1930s, have indicated the ability of several plants suitable for revegetation and soil conservation to survive and spread. Some of the plants noted in this paper could be used to advantage on difficult sites, with reduced establishment and maintenance costs. They will not inhibit high-input development using other species, should this eventually occur in these areas. Sheep's burnet, now commercially available, should be promoted for use on depleted sunny aspects. It is quite palatable, drought-tolerant, requires minimal fertiliser and, once established, is long-lived (Sheppard and Wills, 1985). Chewings fescue, danthonia and zig-zag clover also have potential, mainly for shadier aspects. The spread

of tall oat grass is a matter for some concern as the growth can become very rank unless correctly managed and may be a fire hazard in such situations.

Careful management is required if 'new' pasture plants are to be used successfully in such a variable environment. Middleton *et al.*, (1923) noted the basic management requirements evidenced by the Cockayne plots and these are still very relevant today with higher stock numbers and increased subdivision affecting unimproved tussock grassland (O'Connor, 1982). Improved management systems would greatly increase the survival and productivity of the plants that have demonstrated most potential in the Cockayne trials for revegetation of New Zealand's depleted semi-arid tussock grassland areas. Because of the severity of the Central Otago environment a change in emphasis seems appropriate on land of marginal development capability from increased agronomic production (hence higher fertility regimes) to a more moderate aim of a diversified and sustainable high country vegetation cover and soil conservation at reduced cost. This may be accompanied by more intensive development of land able to be cultivated and irrigated.

With regard to the future of the Cockayne trials, it is considered that those plots containing pasture species and with fences that are relatively intact (i.e., plots 2, 3a, 4, 5, 6, 7, 8, 9, 11 and 12) should be preserved for their historical and botanical value. While future changes in plant composition within the plots are likely to have limited agronomic application they will continue to reflect local farm management

practices, e.g., in autumn 1986 plots 8-12 received an aerial topdressing of sulphur superphosphate (see soil tests).

A number of the plots (2, 3a, 4, 5, 6, 7, 9 and 12) have remained relatively unchanged with moderate or no grazing over the past two decades. With some minor attention to the fences, this situation could be extended for at least a similar period. It would, for instance, provide an opportunity to establish the longevity of individual sheep's burnet plants, some of which appear to be of considerable age. The plots may also help provide a comparison for possible future rabbit control measures which are becoming critical for the Central Otago area. It would be advantageous if regular assessment (at say 5 or 10 yearly intervals) could be made of the plots, including grazing status, soil fertility and botanical composition.

Northburn Station comprises mainly freehold land and the future treatment of the plots lies largely with the runholder. However, the maintenance of the trials should, with the runholder's permission, be administered by those Government Departments with an interest in hill and high country farming (Lands and Survey Department, Department of Scientific and Industrial Research - Grasslands Division, Ministry of Agriculture and Fisheries, Centre for Resource Management - Lincoln College and Ministry of Works and Development - Water and Soil Directorate, or possibly the new Ministry for the Environment).

There is presently a serious conflict between trees and agronomic species within the Cockayne trials. Many feel that the conifers in particular have no aesthetic value in the local landscape, and they are of little economic value unless properly managed in wood lots or shelter belts. Their growth rate and form is also adversely affected by the climatic fluctuations experienced in Central Otago. Removal of conifers from plots 8-11 and the surrounding farmland is therefore considered appropriate to prevent their inevitable spread and dominance on this run country. The original aim of the trials, to investigate revegetation with pasture species, may therefore be preserved even if already considerably modified by changed techniques and lack of upkeep of the fences. This should ensure the continued historical value of the plots and that they remain of interest to agronomists, ecologists and botanists in the future.

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Appendix I: *Species sown and planted on the Cockayne trials.*

A) AS REPORTED IN COCKAYNE, 1922b

i) *Pasture species sown (May 1920, September 1920, March 1921)*

Grasses

Chewings fescue	<i>Festuca rubra</i> L.
Cocks foot	* <i>Dactylis glomerata</i> L.
Crested dogstail	<i>Cynosurus cristatus</i> L.
Danthonia	<i>Danthonia pilosa</i> auct. NZ (<i>Rytidosperma clavatum</i> (Zotov) Connor <i>et</i> Egar)
Kentucky bluegrass	* <i>Poa pratensis</i> L.
Tall fescue	<i>Festuca elatior</i> L. (<i>F.</i> <i>arundinacea</i> Schreb.)
Tall oat grass	* <i>Arrhenatherum elatius</i> (L.) Beauv.
Perennial ryegrass	* <i>Lolium perenne</i> L.
Yorkshire fog	* <i>Holcus lanatus</i> L.
Creeping bent	* <i>Agrostis alba</i> (<i>A. stolonifera</i> L.)
Browntop	* <i>Agrostis tenuis</i> Sibth. (<i>A.</i> <i>capillaris</i> L.)

Legumes

Lucerne	* <i>Medicago sativa</i> L.
Slender birdsfoot trefoil	<i>Lotus angustissimus</i> L.

Herbs

Chicory	<i>Cichorium intybus</i> L.
Yarrow	* <i>Achillea millefolium</i> L.
Catsear	* <i>Hypochaeris radicata</i> L.
Narrow-leaved plantain	<i>Plantago lanceolata</i> L.
Sheep's burnet	<i>Poterium sanguisorba</i> L. (<i>Sanguisorba minor</i> Scop. ssp <i>muricata</i> (Spach) Briq.)

ii. *Pasture species planted (May 1920 or September 1920; sown species above marked. were also introduced by planting).*

Grasses

Poa	<i>Poa laxa</i>
-----	-----------------

Sweet vernal	<i>Anthoxanthum odoratum</i> L.
Blue tussock	<i>Poa colensoi</i> Hook. f.
Couch	<i>Agropyron repens</i> (L.) Beauv. (<i>Elytrigia repens</i> (L.) Beauv.)
Blue wheat grass	<i>Agropyron scabrum</i> Beauv. (<i>Elymus rectisetus</i> (Nees in Lehm.) Love <i>et</i> Connor)

Legumes

Red clover	<i>Trifolium pratense</i> L.
White clover	<i>Trifolium repens</i> L.
Subterranean clover	<i>Trifolium subterraneum</i> L.

Herbs

Perennial sow thistle	<i>Sonchus arvensis</i> L.
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iii) *Tree species sown and planted (May 1920 or September 1920)*

Conifers

Corsican pine	<i>Pinus nigra</i> Arnold.
Ponderosa pine	<i>P. ponderosa</i> Dougl.
Radiata pine	<i>P. insignis</i> (<i>P. radiata</i> D. Don.)

Eucalypts

Tasmanian snow gum	<i>Eucalyptus coccifera</i> Hook. f.
Cider gum	<i>E. gunnii</i> Hook. f.

B) AS REPORTED IN DOUGLAS, 1970

i) *Species sown on to plot 3A and part of plot 4 in 1948*

Grasses

Chewings fescue	<i>Festuca rubra</i> L. spp. <i>commutata</i> Gaud. (<i>F. nigricans</i> Lam.)
Cocksfoot	<i>Dactylis glomerata</i> L.
Tall oat grass	<i>Arrhenatherum elatius</i> (L.) Beauv.
Crested wheat grass	<i>Agropyron cristatum</i> (L.) Gaertn.
Tall wheat grass	<i>Agropyron elongatum</i> (Host.) Beauv.
Bluebunch wheat grass	<i>A. spicatum</i> (Pursh.) Scribn. and Smith.

Blue grama	<i>Bouteloua gracilis</i> (H.B.K.) Lag.	Sweet clover	<i>Melilotus alba</i> Med.
Smooth brome	ex :steuo.	Note: Zig-zag clover (<i>Trifolium medium</i> L.) is not mentioned in the early lists but was apparently established from these sowings.	
Legumes	<i>Bromus inermis</i> Leyss.		
Lucerne	<i>Medicago sativa</i> L.	Herbs	
Subterranean clover	<i>Trifolium subterraneum</i> L.	Yarrow	<i>Achillea millefolium</i> L.

Appendix II: Common/Generic names of species identified on the Northburn plots not introduced by Cockayne.

		Herbs	
Grasses		Mouse-ear chickweed	<i>Cerastium glomeratum</i> Thuill.
Silvery hairgrass	<i>Aira caryophyllaea</i> L.	Californian thistle	<i>Cirsium arvense</i> (L.) Scop.
Ripgut brome	<i>Bromus diandrus</i> Roth.	Hawksbeard	<i>Crepis capillaris</i> (L.) Wallr.
Soft brome	<i>B. hordeaceus</i> L.	Viper's bugloss	<i>Echium vulgare</i> L.
Downy brome	<i>B. tectorum</i> L.	Tussock hawkweed	<i>Hieracium lachenalii</i> Gmel.
Small erythranthera	<i>Erythranthera pumila</i> (Kirk)	Horehound	<i>Marrubium vulgare</i> L.
	Zotov	Scabweed	<i>Raoulia australis</i> Hook. f.
Hard tussock	<i>Festuca novae-zelandiae</i>	Sheep's sorrel	<i>Rumex acetosella</i> L.
	(Hack.) Ckn.	Stonecrop	<i>Sedum acre</i> L.
Barley grass	<i>Hordeum murinum</i> L.	Bladder campion	<i>Silene vulgaris</i> L.
Silver tussock	<i>Poa caespitosa</i> Forst.	Salsify	<i>Tragopogon porrifolius</i> L.
Blue tussock	<i>Poa colensoi</i> Hook. f.	Woolly mullein	<i>Verbascum thapsus</i> L.
Vulpia hairgrass	<i>Vulpia bromoides</i> (L.) S.F.	Moth mullein	<i>Verbascum virgatum</i> Stokes
	Gray	Shrubs	
Legumes		Sweet brier	<i>Rosa rubiginosa</i> L.
Haresfoot trefoil	<i>Trifolium arvense</i> L.	Elder	<i>Sambucus nigra</i> L.
		Wild thyme	<i>Thymus vulgaris</i> L.