THE EFFECTIVENESS OF SOME HERBACEOUS SPECIES FOR MONTANE AND SUBALPINE REVEGETATION

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SUMMARY: The low level of plant nutrients in exposed high-altitude subsoils, and the effects of soil frost and needle ice on plants attempting to colonise these subsoils combine to make natural revegetation very difficult. Artificial revegetation trials established in 1965 at three sites in the Canterbury mountains tested the effect of a fertiliser mixture which supplied a wide range of nutrients, and compared ten herbaceous species as providers of an initial protective cover, and of a cover that would persist.

Fertiliser proved essential to survival of sown species, and Yorkshire fog showed greatest ability to provide quick ground cover. In the absence of further fertiliser over five seasons browntop and Chewings fescue provided the most persistent cover. Several species sown in the trials reseeded, and browntop, Yorkshire fog and white clover showed most ability in re-establishing as volunteers. There were few volunteer native species.

INTRODUCTION

In the period 1965–70, the Tussock Grasslands and Mountain Lands Institute has investigated several aspects of revegetation of eroded soils and screes, principally in the subalpine zone (Dunbar 1970a). The main aim of this work has been to determine the type of fertiliser necessary to give good plant establishment and growth on these infertile sites. Other work has involved the study of establishment of native grass species. At the same time observations have continued on a series of three pilot trials established in the Canterbury mountains in 1965. These trials compared the establishment and growth of 10 herbaceous species (seven grasses, two clovers and yarrow) sown with and without fertiliser. This paper records both the initial results of these trials and the degree of persistence of plots in the years since establishment.

TRIAL SITES

The three sites are referred to throughout as Porter's Pass, Craigieburn and Olympus. All lie within a radius of six miles of Castle Hill homestead, Canterbury, and all consist of severely eroded, strongly leached, high country yellow brown earths.

Both the Porter's Pass and Craigieburn sites have been described in detail previously (Dunbar 1970b). Major features are that Porter's Pass site is at 975 m. (3,200 ft.) on a 27° slope with a west aspect; Craigieburn is at 990 m. (3,250 ft.) on an 8° slope with a south-west aspect. A detailed description of the Olympus site follows:

FIGURE 1. *The Olympus site is a very steep 35° slope at 1128 m. altitude. Plots sown originally with fertiliser are clearly defined with sown but non-fertiliser treated plots between.*

Situation — On the western flank of the Craigieburn Range at an altitude of 1128 m. (3700 ft.) above sea

level near the headwaters of the Ryton River. Map reference NZMS 1, Sheet S 66, 093953.

Slope and Aspect — Slope 35°, on an east-south-east aspect.

Soil — Exposed subsoil, yellowish brown, very friable and unconsolidated remnant of a Kaikoura steepland soil (N.Z. Soil Bureau, 1968). Nutrient status is very low, pH is 5.2.

Vegetation — In areas close to the plot, vegetation is dominated by broad-leaved snow tussock (*Chionochloa flavescens*) with hard tussock (*Festuca novae-zelandiae*) and blue tussock (*Poa colensoi*) in open situations and silver tussock (*Poa laevis*) and blue wheatgrass (*Agropyron scabrum*) dominating areas of soil accumulation.

Climate — There are no records of climate at the site. The nearest climatological station is the Craigieburn Forest Station at a lower altitude (914 m.), at 11 kilometres distance to the north-east. Records for the years 1965–69 inclusive (N.Z. Meteorological Service 1965 *et seq.*) show that the average mean January temperature for the five-year period at Craigieburn Forest was 12.9°C. (55.3°F.) and for July it was 1.3°C. (34.3°F.). For the same five-year period the average annual precipitation was 145.5 cm. (57.3 inches), but there was a wide range of from 105.6 cm. in 1966 to 183.6 cm. in 1968. In the period November 1965 to April 1966 inclusive, the first season of the trials, rainfall at Craigieburn Forest totalled 73.7 cm. (29.01 inches).

MATERIALS AND METHODS

Plant Species

Within the limit of 10 treatments for species, the choice of species was made principally on the basis of success in surface seedings at other lower-altitude and generally drier situations (Douglas 1966). One previously untested species, mountain rye (*Secale montanum*), was included. The species used and the rates of seeding are shown in Table 1.

TABLE 1. *Species Sown and Rate of Seeding*

	SPECIES	SOWING RATE KG/HA	SOWING RATE LB/AC.
1.	Chewings fescue (*Festuca rubra* ssp *commutata*)	14.01	12.5
2.	Browntop (*Agrostis tenuis*)	1.23	1.1
3.	Cocksfoot (*Dactylis glomerata*)	12.55	11.2
4.	Italian ryegrass (*Lolium multiflorum*) and tall fescue (*Festuca arundinacea*)	43.71	39.0
5.	Massey Basyn Yorkshire fog (*Holcus lanatus*)	12.32	11.0
6.	Blue wheat grass (*Agropyron scabrum*)	138.98	124.0
7.	Mountain rye (*Secale montanum*)	75.65	67.5
8.	Yarrow (*Achillea millefolium*)	2.35	2.1
9.	"Grasslands Huia" white clover (*Trifolium repens*)	10.53	9.4
10.	Suckling clover (*Trifolium dubium*)	7.06	6.3

The mixture of Italian ryegrass and tall fescue came from heavy ryegrass contamination in an uncertified line of tall fescue seed. Seeding rate for each species was calculated to give one viable seed per square inch of ground surface (1 seed per 6.5 cm^2). An exception was mountain rye for which seeding was reduced to one half this rate because of the small quantity of seed available.

Chewings fescue, browntop, cocksfoot and white clover were obtained as commercial lines of seed. The Yorkshire fog came from Massey University selected plants. Blue wheatgrass seed was harvested at Lincoln College from a Central Otago strain. Tall fescue was from a paddock of S170 at Lincoln College. Mountain rye seed was received from Iran. Yarrow and suckling clover were obtained as cleanings from a local seeds firm.

Fertiliser

The fertiliser mixture, where applied, consisted of superphosphate and calcium ammonium nitrate, each at 502 kg./ha. (4 cwt./acre), magnesium sulphate and potassium sulphate, each at 125.5 kg./ha. (1 cwt./acre), copper sulphate and zinc sulphate, each at 11.2 kg./ha. (10 lb./acre), borax at 22.4 kg. ha. (20 lb./acre) and sodium molybdate at 0.35 kg./ha. 5 oz./acre).

Experimental Design

For each of the 10 plant species there were two fertiliser treatments, with fertiliser and without, and treatments were replicated three times to give 60 plots at each of the three trial sites. Each plot measured 10 links by 10 links to give an area of 0.001 acre (4.05m^2). To avoid contamination of "no fertiliser" plots which could result from downslope movement of fertiliser, the "fertiliser" and "no fertiliser" treatments in each replicate were placed in separate strips in line with the slope, and randomisation of species was restricted to being within these fertiliser treatments.

Establishment

Seed and fertiliser was broadcast without prior or subsequent treatment of the ground surface. Plots at the three sites were established within a six day period — specifically on the following dates: Porter's Pass 3–4 November, Craigieburn 5 November, and Olympus, 9 November 1965.

TABLE 2. *Mean Seedling Emergences at Three Sites*
(*seedlings per square foot sample*)

	Porter's Pass		Craigieburn		Olympus	
	Fert.	No Fert.	Fert.	No Fert.	Fert.	No Fert.
Chewings fescue	62	44	48	47	20	38
Browntop	48	6	55	63	29	11
Cocksfoot	77	55	30	23	30	29
Ryegrass/fescue	56	29	24	62	73	26
Yorkshire fog	46	62	46	48	37	13
Mountain rye	29	59	4	9	32	49
Blue wheat grass	96	86	20	9	78	115
Yarrow	31	83	62	65	71	41
White clover	33	31	55	58	23	26
Suckling clover	45	23	35	32	12	15
Mean	52	48	38	46	41	37

RESULTS

(a) THE FIRST SEASON

Seedling Establishment and Growth

By the beginning of January 1966, two months after sowing, the effect of fertiliser was apparent in the greater vigour of the plants in the treated plots. By contrast, plants in untreated plots were generally less than half the size and were yellowish-green in colour.

Counts of seedlings within a randomly placed one square foot frame were made during the first week in January (Table 2).

Although there were large differences in vigour between fertiliser treated and untreated plots, the within-site analysis of the figures for seedling counts did not show any significant differences between seedling numbers from these two treatments.

The main importance of these seedling counts was to show that more than sufficient seedlings were present initially to provide the basis for an adequate ground cover, with the possible exception of blue wheat grass and mountain rye at Craigieburn and suckling clover at Olympus. No evidence was available to explain the anomalies with regard to mountain rye and blue wheat grass. Birds or mice may possibly have eaten the majority of these large seeds scattered on the soil surface at the Craigieburn site.

By mid-March at Porter's Pass in fertiliser treated plots, plants of mountain rye had produced leaves of up to 20 cm. and flowering culms of 75–80 cm., although flowering had not occurred. Ryegrass plants similarly were heading to flower, Yorkshire fog, blue wheat grass and cocksfoot had produced leaves up to 16 cm. in length, while Chewings fescue and browntop were at the 10–12 cm. level. Yarrow in turn had leaves, on average, about 10 cm. long and occasional flower heads. White clover plants were approximately 8 cm. tall with a spread of 10–12 cm. and suckling clover plants with a spread of 12–15 cm. were flowering.

Whereas the plants with fertiliser continued steady growth through the summer and autumn, the untreated plots showed little growth after January. No detailed records of the *untreated* plots were taken after January but general observation showed that they entered the winter with little protective cover. Few seedlings survived the winter at any of the three sites, and later observations and measurements were confined to those plots which had been given the fertiliser mixture.

Stage of Growth Prior to First Winter

During the first season visual assessments were made of "vigour" of growth and the extent of ground cover achieved by species under fertiliser treatment. For vigour assessments species were rated in each replicate against Yorkshire fog, and no statistical interpretation has been attempted. Table 3 gives the assessment in late autumn–early winter before frost-kill of herbage had occurred. At this time Yorkshire fog at Porter's Pass and Craigieburn had densely tillered plants with leaves 20–25 cm. long. At Olympus, growth was more vigorous and leaves were from 25–30 cm. long.

TABLE 3. *Plant Vigour Ratings — Autumn 1966*
(*mean of 3 replicates — Yorkshire fog 100*)

	Porter's Pass	Craigieburn	Olympus
Yorkshire fog	100	100	100
Cocksfoot	70	77	80
Ryegrass/fescue	73	60	73
Mountain rye	67	23	77
Blue wheatgrass	60	50	60
Browntop	27	53	50
Chewings fescue	43	37	40
Yarrow	43	23	60
White clover	17	23	23
Suckling clover	50	43	53

The relative vigour of species was similar for each site with Yorkshire fog clearly superior at all three. Low seedling counts for mountain rye at Craigieburn had carried through to a low vigour rating in the autumn, but blue wheat grass at the same site was apparently less affected. White clover rated lowest for vigour in all three sites, and the slower establishing species — browntop and Chewings fescue — were outranked by the other grasses (except for mountain rye at Craigieburn).

Ground Cover Prior to First Winter

Vigour of growth is important, but, in an environment where formation of needle ice and frost heaving are important causes of plant destruction, it is also vital to have a high proportion of the ground surface protected against rapid freezing and thawing (Gradwell 1962). Plots were visually assessed for the degree of ground protection achieved by the individual species on the basis of percentage of surface area covered as at late autumn 1966 (Table 4).

A ground cover of at least 50% of surface area had been achieved by most species at each of the three sites by the end of the first growing season. Yorkshire fog had the highest mean percentage cover at each of the three sites. All species except blue wheat grass had their highest percentage cover at the Craigieburn site.

Comparison of species within sites showed that at Porter's Pass there were no significant differences in the first season ground cover given by Yorkshire fog, blue wheatgrass, Chewings fescue, mountain rye, yarrow, cocksfoot and the ryegrass/tall fescue mixture. All of these species except cocksfoot gave significantly better results than white clover, browntop and suckling clover, although cocksfoot in turn was significantly better than browntop and suckling clover.

FIGURE 2. *Yorkshire fog produced the most vigorous growth and the best ground cover of any species at all three sites in the first season. This cover is on a 35° slope, five months after sowing.*

More uniform results among the species were obtained at Craigieburn, but Yorkshire fog again gave the best results followed closely by browntop. The mean figure for cover for each of these two species was significantly larger than the mean for the poorest species, mountain rye. Differences within the range of browntop to mountain rye

TABLE 4. *Mean Percentage Ground Cover from 10 Species at Three Sites in First Season*

	Porter's Pass	Craigieburn	Olympus	Significance of differences (Sites) P <0.01	P <0.05
Yorkshire fog	70.0 aA	86.7 a	83.3 aA	—	—
Wheatgrass	66.7 aA	60.0 ab	60.0 abAB	—	—
Chewings fescue	56.7 aAB	66.7 ab	26.7 cdBCD	Cb>0	PP>0
Ryegrass/fescue	53.3 aABC	70.0 ab	60.0 abAB	—	—
Mountain rye	53.3 aABC	53.3 b	50.0 bcABC	—	—
Yarrow	53.3 aABC	66.7 ab	60.0 abAB	—	—
Cocksfoot	50.0 abABC	76.7 ab	56.7 bAB	—	Cb>PP
White clover	26.7 bc BC	60.0 ab	13.3 dD	Cb>0. Cb>PP	—
Browntop	20.0 cC	83.3 a	46.7 bcBCD	Cb>PP, Cb>0	0>PP
Suckling clover	20.0 cC	70.0 ab	20.0 dCD	Cb>PP, Cb>0	—

(Letters for multiple range tests refer to species comparisons within sites.)

were not significant. The results for blue wheatgrass plots and for white and suckling clover are over-valued on this site because of an early invasion by volunteer browntop.

At the Olympus site, Yorkshire fog gave best results, with blue wheatgrass, yarrow and the ryegrass/tall fescue mixture equal in second place but not significantly different. The cover from Yorkshire fog was, however, significantly better than all species except these three. Results from white clover and suckling clover were poor with cover levels significantly below all other species except Chewings fescue.

A comparison of the figures for cover for each species in each of three sites showed that for five species, namely Yorkshire fog, mountain rye, blue wheatgrass, yarrow and the ryegrass/fescue mixture, the differences amongst sites were not significant. On the other hand, for browntop, white clover and suckling clover the difference in favour of the Craigieburn site over the other two sites was highly significant. For Chewings fescue the difference in cover between the Craigieburn site and the Olympus site was highly significant, and for cocksfoot significantly better results were achieved at Craigieburn than at Porter's Pass.

TABLE 5. *Plant Vigour Ratings — Late Spring 1966 (mean of three reps. Yorkshire fog 100)*

	Porter's Pass	Craigieburn	Olympus
Yorkshire fog	100	100	100
Cocksfoot	100	66	92
Ryegrass/fescue	106	83	75
Mountain rye	124	83	183
Blue wheatgrass	94	73	92
Browntop	47	73	67
Chewings fescue	53	78	58
Yarrow	65	33	42
White clover	35	33	33
Suckling clover	12	11	0

(b) CHANGES IN SECOND SEASON

Vigour

Ratings for vigour of species in the late spring of 1966 showed some marked changes in the growth of species relative to Yorkshire fog. (Table 5.)

At this time there was little active tiller growth in Yorkshire fog plots. All species except suckling clover were rated as having improved their vigour rating relative to fog, although fog was still superior to most species. Exceptions where fog was rated inferior were to mountain rye and the ryegrass/tall fescue mixture at Porter's Pass and to the mountain rye treatment at Olympus.

Ground Cover

The ground cover assessments for the various treatments for the three sites are shown in Table 6.

For the majority of species, figures for ground cover showed a fall since the previous autumn. Yorkshire fog still maintained the highest percentage cover for treatments at Porter's Pass and Olympus but had been relegated to second place at Craigieburn by browntop.

At this stage, at Porter's Pass, ground cover from fog was significantly better than for all species except Chewings fescue. Chewings fescue was significantly better than browntop and the two clovers.

There had been a marked decrease in the percentage ground cover for most species at Craigieburn, but browntop had remained at the same level, and there had been only a slight decrease for fog. Browntop and fog were now giving significantly better cover than Chewings fescue, blue wheatgrass, mountain rye and the two clovers.

TABLE 6. *Mean Percentage Ground Cover from 10 Treatments at Three Sites in Second Season*

	Porter's Pass	Craigieburn	Olympus	Significance of differences (Sites) P <0.01	P <0.05
Yorkshire fog	76.7 aA	80.0 abA	80.0 aA	—	—
Chewings fescue	60.0 abAB	53.3 cABC	43.3 bBC	—	—
Wheatgrass	46.7 bcABC	46.7 cdBC	50.0 bAB	—	—
Cocksfoot	46.7 bcABC	63.3 abcAB	50.0 bAB	—	—
Yarrow	46.7 bcABC	56.7 bcAB	56.7 abAB	—	—
Mountain rye	43.3 bcBC	23.3 defCD	46.7 bAB	—	0>Cb
Ryegrass/fescue	40.0 bcBC	60.0 abcAB	60.0 abAB	—	—
Browntop	33.3 cBCD	83.3 aA	53.3 bAB	Cb>PP, Cb>0	—
White clover	23.3 cdCD	43.3 cdeCD	13.3 cC	—	Cb>0
Suckling clover	6.7 dD	10.0 fD	13.3 cC	—	—

(Letters for multiple range tests refer to comparisons within sites.)

At Olympus, fog retained its superiority with cover significantly better than all species except yarrow and ryegrass/fescue. White clover and suckling clover remained the worst plots, but two plots of white clover had received severe damage from winter gravel and mud flows.

There was little difference between sites in the cover provided by individual species, with only browntop and white clover now giving significantly better cover at Craigieburn than at other sites, and mountain rye giving significantly better cover at Olympus than at Craigieburn. Inter-site differences for seven treatments, that is: Yorkshire fog, blue wheatgrass, yarrow, ryegrass/tall fescue, cocksfoot, Chewings fescue and suckling clover, were not significant. Wetter ground conditions at Craigieburn appear to have favoured browntop and white clover.

Flowering and Seed Set

During the second summer there was a liberal flowering and seed set of Yorkshire fog at all three sites. Seed was set in good quantities also on Chewings fescue and browntop plots but was very poor for other species.

Much of the seed produced, especially of Yorkshire fog, germinated at the margins of the plots, but seedlings subsequently died in the unprotected infertile subsoil. Some seedlings established in plots other than the "parent" plot and persisted into later seasons, and this is discussed later in the paper.

(c) PERSISTENCE OF GROUND COVER

Species and Site Comparisons

The total cover of living and dead vegetation was measured in both the fourth and fifth seasons by a point analysis method with records of 100 points in each plot. The detailed results for the fourth season (1968–69) are not given in this paper, since the fifth season records confirmed and amplified the earlier trends. Briefly, the fourth season records showed that there was very little active growth for most species and that some plots had suffered very severely from erosion. While there was still much dead plant material protecting the soil from raindrop, wind and frost action, few plots had more than 50% of the surface area protected.

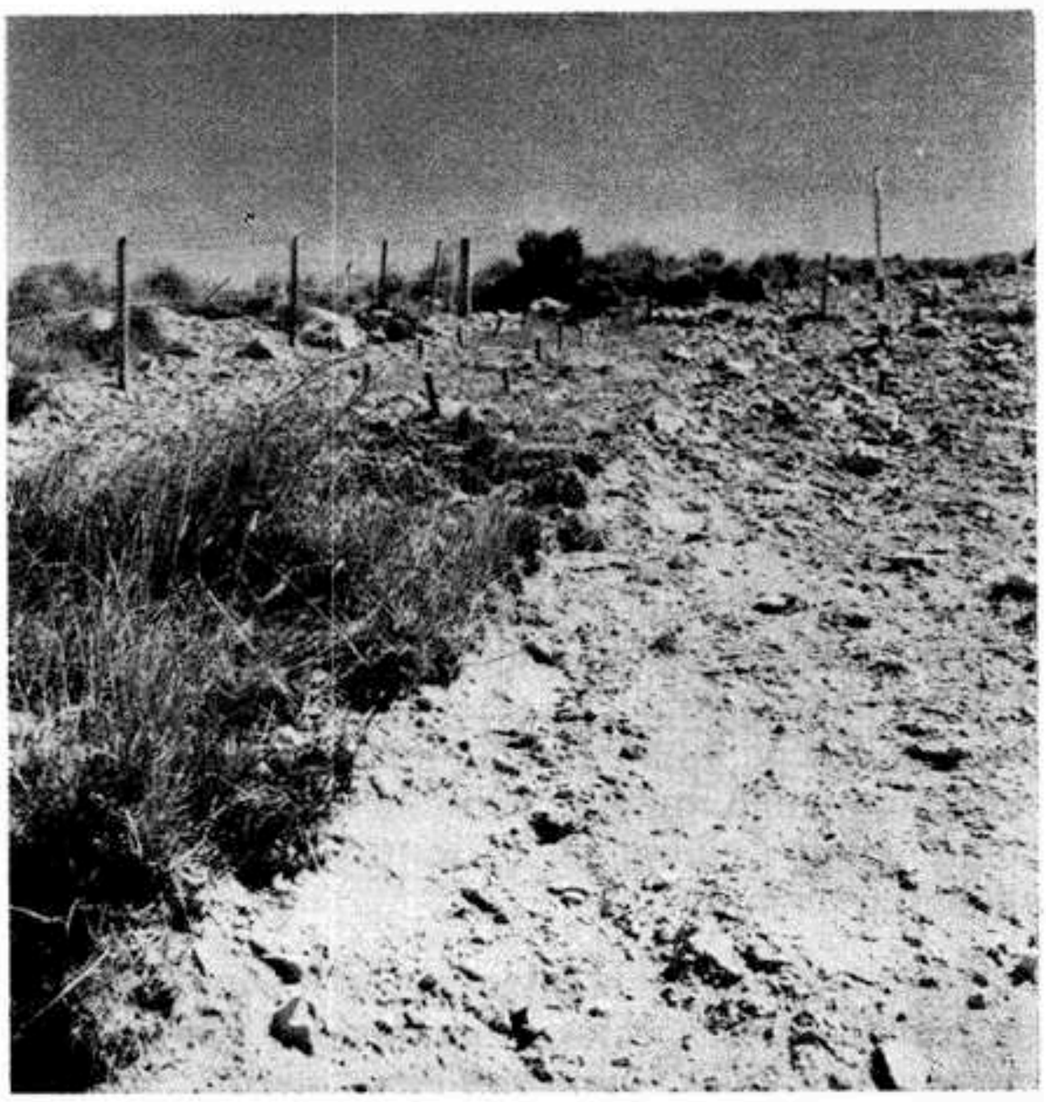

FIGURE 3. *After five seasons the grass species sown with fertiliser are seen to have exerted a strong stabilising effect on subsoil on this slope.*

TABLE 7. *Mean Percentage Hits on Ground Cover for Sown Species and Dead Material in Fifth Season*

	Porter's Pass	Craigieburn	Olympus	Significance of differences (Sites) P <0.01	P <0.05
Chewings fescue	43.0 aA	37.7 bAB	29.3 abAB	—	—
Yorkshire fog	37.0 abAB	31.3 bcB	38.0 aA	—	—
Wheatgrass	35.3 abAB	25.3 bcB	23.0 abcABC	—	—
Cocksfoot	27.0 abcABC	29.7 bcB	23.0 abcABC	—	—
Yarrow	24.7 abcdABC	24.3 bcB	29.3 abAB	—	—
Browntop	20.7 bcdABC	61.3 aA	43.0 aA	Cb>0>PP	—
Mountain rye	20.3 bcdABC	15.3 cB	23.3 abcABC	—	—
Ryegrass/fescue	17.3 bcdABC	28.3 bcB	10.0 bcdBC	—	—
White clover	14.3 cdBC	25.3 bcB	0.3 dC	Cb>0	—
Suckling clover	4.3 dC	25.0 bcB	6.3 cdBC	Cb>PP, Cb>0	—

(Letters for multiple range tests refer to comparisons within sites.)

Results for point analysis in the 1969–70 season, the fifth season after sowing, are shown in Table 7. This shows hits recorded on the original plant species sown in each plot, both living and dead plant material, but specifically excludes records of other species which volunteered after sowing.

The table shows that by the fifth season only browntop at Craigieburn had a mean figure for cover greater than 50%. Compared with the second season, Yorkshire fog had yielded first place to Chewings fescue at Porter's Pass, and to browntop at Olympus, and had fallen to third best behind browntop and Chewings fescue at Craigieburn.

At Porter's Pass, cover from Chewings fescue was now significantly better than from browntop, mountain rye, ryegrass/fescue and the clovers.

At Craigieburn, cover from browntop was now significantly better than from any other species. Fog as well as browntop gave significantly better results than mountain rye.

At Olympus, figures for both browntop and fog were significantly higher than for the ryegrass/fescue mixture, suckling clover and white clover. However, it should be stated that one plot of ryegrass/fescue had been almost completely destroyed by undermining erosion, and two white clover plots completely destroyed by "overwhelming" erosion.

In the site to site comparison of cover remaining for any one species, relationships showed no important changes from the second season. Significant differences exist for browntop, white clover and suckling clover, but the clover results have little meaning because of destruction of plots at Olympus and generally low figures for suckling clover.

Influence of Type of Cover

Previous tables have shown that a favourable cover advantage to a species in the early years did not ensure a continuing advantage in persistence. Thus, although Yorkshire fog began in the first season with the highest percentage cover at all three sites, by the end of the fifth season it had less than the best at all sites.

To simplify comparisons of the ability of a species to give persistent soil protection, cover remaining in the fifth season in all plots has been expressed as a percentage of the ground cover in the second season. The mean values for the various species/site combinations are shown in Table 8. White clover and suckling clover have been omitted from analysis.

There were significant differences amongst the means for species over the trial as a whole. Cover persistence from both browntop and Chewings fescue is significantly better than from Yorkshire fog and the ryegrass/tall fescue combination, and, in addition, blue wheatgrass showed significantly better results than the ryegrass/tall fescue mixture.

Since active frost lift occurs on unprotected soil surfaces, the fastest rate of deterioration in cover might be expected to occur on those plots which had least cover in the early stages of the trial. Table 8 shows that Yorkshire fog, however, which had the best cover initially, was one of the poorest at the end of the period and, obviously, the resistance of dead herbage to weather conditions is a major factor here. A calculation of the correlation coefficient for the relationship between the extent of cover in plots in the second season and the percentage of that cover remaining in the fifth season gave a non-significant value of $r = 0.1369$ lending further emphasis to the suggestion

TABLE 8. *Fifth Season Cover as a Percentage of the Ground Cover in the Second Season*

	Porter's Pass	Craigieburn	Olympus	Mean for species	Significance of differences $P < 0.05$
Browntop	59.3	72.3	83.7	71.8	a
Chewings fescue	72.3	68.3	63.3	68.0	a
Wheatgrass	75.0	56.7	45.0	58.9	ab
Mountain rye	50.0	62.3	46.3	52.9	abc
Cocksfoot	61.7	49.3	44.0	51.7	abc
Yarrow	55.7	42.0	54.7	50.8	abc
Yorkshire fog	47.3	40.3	45.7	44.4	bc
Ryegrass/fescue	48.0	50.0	13.3	37.1	c
Mean for site	58.7	55.2	49.5	—	

that the extent of ground cover in the early stages was *not* a major factor in determining the rate of deterioration.

(d) SECONDARY ESTABLISHMENT IN PLOTS

Host Plots

Earlier in this paper mention was made of the seed setting of some species and the subsequent establishment of plants in other plots. Point analysis records made late in the 1969–70 season showed the effect of this secondary invasion on the cover of plots.

The effect of this secondary establishment was most pronounced at the Craigieburn site, where 30% of the total hits on cover were from volunteers. By comparison, at Porter's Pass and Olympus, volunteers were 11% and 9% respectively. There were also some large differences in the numbers of hits on volunteers amongst the various "host" plots at each site. Table 9 shows the total number of hits on volunteer species by host plot at each site, with each total consisting of the aggregate of three replicates.

At Porter's Pass, most hits on volunteers were in the white clover and mountain rye plots, with suckling clover close behind. There was a small total of volunteers at Olympus, but here most were in the mountain rye plots with cocksfoot second. While it would be unwise to make many deductions from the rather meagre records at Porter's Pass and Olympus, it does seem that in both sites the tall, sparse growth of mountain rye provided a favourable environment for establishment of other species. White clover plots at Porter's Pass and at Craigieburn provided good nurseries for volunteers, but Craigieburn was unusual in that highest numbers of volunteers were recorded on the wheatgrass plots. This may be attributed in part to the lack of competition resulting from very poor establishment of wheatgrass in the first year at this site. At the same time volunteers in the mountain rye plots were unaccountably few in proportion to the bare ground available. With this exception, volunteers have favoured those plots where initial cover of host species was weakest and where some residual effect of fertiliser could be expected. Clover plots received the same initial fertiliser as the grass plots, and, in addition, the nitrogen fixed by the clovers would assist the long-term survival of volunteers.

Volunteer Species

An unusual feature of the distribution of the various volunteer species was the extremely high incidence of browntop at Craigieburn. Table 10 shows that browntop accounted for 45.5% of all volunteers at this site. Much of this browntop had started to appear during the second season, prior to flowering of the plot-sown browntop, but further spread from the plots almost certainly occurred later.

White clover proved to be a strong volunteer too, at this site, accounting for another 25.7% of all point records. Sweet vernal originating from without the plots was the next most frequently hit species.

From the relatively few records at Olympus, browntop and white clover were again top-scorers,

TABLE 9. *Volunteers Within Host Plots*
(*total hits at fifth season*)

Host plots	PORTER'S PASS		CRAIGIEBURN		OLYMPUS	
	Hits on volunteers	% of total hits	Hits on volunteers	% of total hits	Hits on volunteers	% of total hits
Chewings fescue	0	0	12	2.9	1	1.5
Browntop	7	7.5	18	4.4	3	4.5
Cocksfoot	4	4.3	37	9.0	15	22.4
Ryegrass/fescue	9	9.7	45	11.0	2	3.0
Yorkshire fog	1	1.1	34	8.3	0	0.0
Mountain rye	22	23.6	27	6.6	16	23.9
Wheatgrass	9	9.7	78	19.1	7	10.4
Yarrow	2	2.1	27	6.6	11	16.4
White clover	23	24.7	75	18.3	5	7.5
Suckling clover	16	17.2	56	13.7	7	10.4
Total	93	100.0	409	100.0	67	100.0

TABLE 10. *Number of Hits on Volunteer Species — Fifth Season*

Volunteer Species	PORTER'S PASS No. of hits	%	CRAIGIEBURN No. of hits	%	OLYMPUS No. of hits	%
Chewings fescue	7	7.5	11	3.7	5	7.5
Browntop	8	8.6	186	45.5	13	19.4
Cocksfoot	5	5.4	1	0.3	6	8.9
Yorkshire fog	26	28.0	16	3.9	2	3.0
Blue wheatgrass	3	3.2	0	0.0	10	14.9
Yarrow	3	3.2	10	2.4	5	7.5
White clover	10	10.7	105	25.7	13	19.4
Suckling clover	0	0.0	16	3.9	0	0.0
Flat weeds	12	12.9	25	6.1	6	8.9
Sweet vernal	9	9.7	30	7.3	0	0.0
Native species	10	10.7	9	2.2	7	10.4

while at Porter's Pass, Yorkshire fog was clearly the most frequently hit.

Over all sites, no volunteer plants of ryegrass, tall fescue or mountain rye were recorded. Cocksfoot, wheatgrass, yarrow and suckling clover were the next least successful of the sown species in re-establishing as volunteers. Native species other than the wheatgrass sown were also sparse, but small numbers of plants of *Cassinia, Anisotome, Luzula, Wahlenbergia, Epilobium* and *Gnaphalium* were recorded.

CONCLUSIONS

This trial reaffirmed emphatically the need for fertiliser to ensure winter survival of sown plant species on exposed, low fertility mountain subsoils. It showed that seed of a variety of species gave satisfactory germination and establishment from surface broadcast seeding in this region of good late spring and summer rainfall. Aided by a complete fertiliser, several species showed ability for rapid growth and rapid development of ground cover in the first season. Yorkshire fog was superior in these abilities to other species tested. White clover and suckling clover were two of the poorer establishing species, but the conditions under which the clover was sown were generally unfavourable for clover establishment.

In the absence of maintenance supplies of fertiliser, all plots showed progressive deterioration in ground protection after the second season, although browntop, white clover and Yorkshire fog showed good ability to volunteer from self-seeding. Although establishing and growing more slowly than fog, browntop and Chewings fescue showed greater ability to persist as protective ground cover.

After five growing seasons a significantly higher proportion of cover survived from browntop and Chewings fescue than from Yorkshire fog and a ryegrass/tall fescue mixture, and browntop, Chewings fescue and Yorkshire fog were generally superior to the other species tested in total residual ground cover. Despite differences in slope and exposure amongst the three sites, most individual species did not show significant differences in effectiveness from site to site. The rate of deterioration of stands was also similar at all sites.

There were large variations in the distribution of volunteer species amongst the host plots, but it appeared that presence of bare areas in host plots during early years when there was a residual fertiliser effect was chiefly responsible for a high incidence of volunteers in some plots. Chewings fescue plots appeared least receptive to volunteer species. Browntop, Yorkshire fog and white clover were the most consistent volunteer species. Few native species established within the plots.

The trial demonstrated the possibility of establishment of an effective ground cover on three difficult sub-alpine sites without resort to expensive physical protection of the soil. There is little doubt that with clover introduction and regular fertiliser applications, such protective cover could be maintained against erosion from within. The practicability of such treatment on a large scale depends finally on how we decide to measure the cost.

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