SOWING NATIVE TUSSOCK SPECIES IN HIGH ALTITUDE REVEGETATION TRIALS

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SUMMARY: Although a cover of grasses and legumes may be established on exposed mountain subsoils through seeding and the use of a complete fertiliser, this cover is not likely to last for more than a few years without the application of more fertiliser. Native tussock species once established in the protection of other low-growing species might persist and provide stability over a longer period.

This paper describes the early results achieved on two sites in the Canterbury mountains, through sowing seed of four tussock species under five cover treatments. Sowing of seed of *Notodanthonia setifolia* produced very few seedlings but blue tussock, hard tussock and silver tussock gave reasonable results. Highest emergence was recorded under the least cover on the control plots, and there was, in general, an inverse relationship between cover treatment density and emergence of tussock seedlings. Survival of tussock seedlings over the first eighteen months from sowing was, however, in direct positive proportion to the amount of cover present.

Growth of tussock seedlings was slow at both trial sites. Tiller numbers tended to be greatest in plots with least competition from cover species. Tussocks remaining amongst cover after the first winter tended to decrease in size and vigour over the second growing season.

INTRODUCTION

Investigations into the possibility of revegetating exposed subsoils and screes in mountain areas first became a major part of the work of the Tussock Grasslands and Mountain Lands Institute in 1965. Pilot trials laid down at three sites in the Canterbury high country in that year tested the effect of a complete fertiliser mixture on establishment and growth of 10 herbaceous species, including one native grass. This work was followed in 1966 by field trials at 10 high altitude sites throughout the South Island and by glasshouse pot trials on subsoils from these 10 sites, all designed to determine what nutrients were needed as additives to promote satisfactory establishment and growth of grasses and clovers. (Tussock Grasslands and Mountain Lands Institute 1967.) Some of the difficulties associated with the establishment and maintenance of a protective cover at high altitude have been discussed by O'Connor and Lambrechtsen (1967), O'Connor (1967), and Holloway (1969).

Although good establishment and growth of grasses was obtained in the Institute's trials in 1965, work of the above authors had indicated that vigour could decline markedly after 2–3 years if no more fertiliser was applied. In the 1965 trials some plants of native tussock species had established as volunteers and grown well in the fertilised plots. This suggested the possibility that such species, which were slow-growing initially but which might be more persistent in low-fertility soils, could be included for long-term effect in sowings of quick-growing exotic species.

In October 1967, trials were laid down at two eroded mountain sites to study the establishment, growth and survival of four native tussock species when sown with other herbaceous species. Seed of *Pinus contorta* was sown in addition to the native species but these results are not included in this paper.

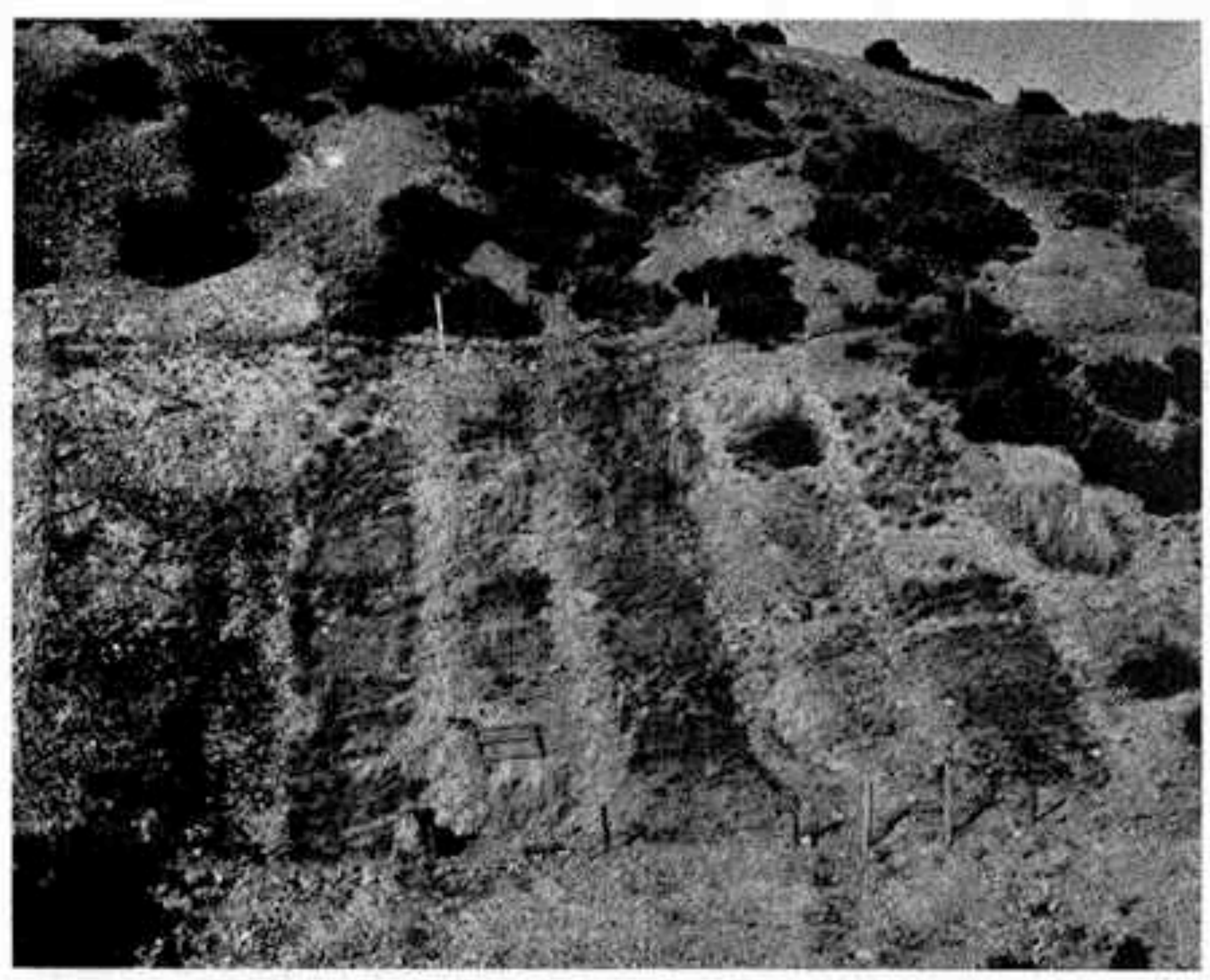

FIGURE 1. *The trial site near the summit of Porter's Pass, Canterbury, on a west-facing slope of 27 degrees at 3,200 ft. altitude.*

TRIAL SITES

(a) *Porter's Pass*

Situation — Near the summit of Porter's Pass at 3,200 ft. above sea level. Map reference N.Z.M.S. 1, Sheet S74, 224855.

Slope and Aspect — Slope 27°, on west aspect but exposed to north-west and southerly winds.

Soil — Severely eroded, strongly leached high country yellow-brown earth, belonging to the Kaikouran soil set. Surface material consists of a mixture of subsoil and fine greywacke fragments, the present depth varying from 2–6 in. over shattered greywacke rock. The depth of soil removal in mid-slope has possibly been as much as 18 in. Soil test figures for calcium, potassium, phosphorus and magnesium are low to very low, and the pH is 5.3.

Vegetation — Vegetation in the vicinity is dominated by *Chionochloa flavescens* and *C. rigida*, in association with *Dracophyllum acerosum*.

Climate — Climate in the Porter's Pass and Foggy Peak Ridge area has been described in detail by Molloy (1963). He interpreted the climate of Foggy Peak Ridge as relatively cool and moist but stated that the region is subjected periodically to the effects of severe winds. He concluded that the mean annual rainfall for sites he measured is probably about 100 cm. (approx. 39 in.). There is a strong funnelling effect of north-west and south-west winds through Porter's Pass. During the winter of 1968 exceptionally heavy snow covered the area.

FIGURE 2. *The Craigieburn site is a gently-sloping but windswept saddle at 3,350 ft. on the fringe of the Craigieburn Range.*

(b) *Craigieburn*

Situation — On the eastern flank of the Craigieburn Range at an altitude of 3,250 ft. above sea level and adjacent to Bridge Hill. Map reference N.Z.M.S. 1, Sheet S66, 194026.

Slope and Aspect — Slope 8°, with slight south-west aspect but exposed to westerly winds.

Soil — Exposed subsoil with development of an erosion pavement. The original soil was a strongly leached high country yellow-brown earth tentatively correlated with the Cass soil set. Estimated depth of soil removal is 12–15 in., with some re-sorting of material on the slope. Soil test figures for calcium, potassium, phosphorus and magnesium are low to very low, and the pH is 5.4.

Vegetation — On surrounding areas there is much *Cassinia* with occasional *Chionochloa rigida*. The low ground cover is mainly browntop (*Agrostis tenuis*), but blue tussock (*Poa colensoi*), hard tussock (*Festuca novae-zelandiae*) and some *Notodanthonia setifolia* are present.

Climate — Morris (1965) gave results of climate investigations in the Craigieburn Range and included figures for Nursery Hill Station which is approximately half a mile from the trial site. For the three years 1961–63 inclusive, precipitation at Nursery Hill was 59.5, 62.6 and 58.7 in. respectively. The three-year average mean monthly temperature for this station ranged from 35°F. in July to 58°F. in January. The mean frost-free period per year during the same period was 115 days.

MATERIALS AND METHODS

(a) *Cover treatments*

Five cover treatments with four replicates were sown at each site, at Porter's Pass on 20 October 1967 and at Craigieburn on 25 October 1967. Treatments were:—

1. No seeding
2. Inoculated "Huia" white clover (*Trifolium repens*)
3. Chewings fescue (*Festuca rubra ssp. commutata*)
4. Browntop (*Agrostis tenuis*)
5. Massey Basyn Yorkshire fog (*Holcus lanatus*)

Seeding of each cover species was at a rate calculated to give one viable seed per square inch of ground surface.

(b) *Tussock species*

Twenty seeds of each of four native tussock species were sown within each cover treatment plot using a planting frame technique for placement as described by Cullen (1965). There were then within each plot a total of 80 seeds of four tussock species, 400 seeds within each replicate and 1,600 seeds within each site. Seeds of each of the native species were examined on glass over a bright light before sowing in an attempt to ensure that only whole seeds were sown.

FIGURE 3. *The wooden frame used for tussock sowing and for relocating seedlings in position on one of the control plots.*

The species sown were mountain danthonia (*Notodanthonia setifolia* (Hook. f.) Zotov)*, blue tussock (*Poa colensoi* Hook, f.), hard tussock (*Festuca novae-zelandiae* (Hack) Ckn.), and silver tussock (*Poa laevis* R. Br.). The origins of the seed and the laboratory germination at time of sowing are shown in Table 1.

* Plant nomenclature according to *Standard common names for weeds in New Zealand*, N.Z. Weed and Pest Control Society, Wellington, 1969.

TABLE 1. *Tussock seed origins and germination at time of sowing.*

SPECIES	SEED ORIGINS	LABORATORY GERMINATION
Mountain danthonia	Clarence River head-waters 1967	52–96% (1)
Blue tussock	Clarence River head-waters 1967	62% (2)
Hard tussock	Lincoln 1966, original seed from Mackenzie plain	95%
Silver tussock	Near Lake Lyndon 1967	87%

Note: (1) The total germination and rate of germination of different samples of mountain danthonia varied markedly with different test conditions, but the possible causes of this variation cannot be discussed in this paper.

(2) Blue tussock seed from Clarence was used for Porter's Pass sowings. At Craigieburn the blue tussock seed was from a 1965 Mackenzie County collection, the germination of which was unknown at the time of sowing.

(c) *Fertiliser*

Fertiliser was applied to all plots. Plots with the three grass species and the "no seeding" or control plots received a dressing of the following mixture:—

Urea	208 lb./acre
Superphosphate	4 cwt./acre
Magnesium sulphate	1 cwt./acre
Potassium sulphate	1 cwt./acre

On clover plots urea was omitted from this mixture and sodium molybdate, at 4 oz. per acre, was added.

Fertiliser and cover treatment seedings were broadcast onto the ground after the tussock seeds had been planted just beneath the soil surface.

At Porter's Pass records of tussock seedlings were taken in December 1967, May 1968, September 1968 and April 1969. The September 1968 and April 1969 records included measurements of seedling height and tiller numbers. At Craigieburn the counts and measurements were made in May 1968 and May 1969.

RESULTS

EMERGENCE AND SURVIVAL OF TUSSOCK SEEDLINGS

(a) *Porter's Pass*

Emergence — Emergence of seedlings of *Notodanthonia setifolia* was disappointingly poor considering the good germinations obtained in the laboratory tests. Only 3% emerged in the first season compared with laboratory germinations ranging from 52–96%. Therefore, in the account which follows, results from seedings of blue tussock, hard tussock and silver tussock only will be given.

TABLE 2. *Emergence of tussock seedlings —Porter's Pass.*

	No. emerged	% of sown	% of viable
Blue tussock	141	35	57
Hard tussock	220	54	58
Silver tussock	211	53	59

Table 2 shows that there was a low emergence of blue tussock as a percentage of seed sown. It also shows that when allowance is made for lower viability of the seed, emergence is similar to that of other species.

Table 3 compares the emergence of these three tussock species under each of the five cover treatments, when an adjustment has been made for viability.

TABLE 3. *Emergence of tussock seedlings as a percentage of viable seed — Porter's Pass.*

	COVER TREATMENT					
	Control	White clover	Y'shire fog	Chewings fescue	Browntop	Mean
Blue tussock	70.5	62.5	44.4	58.5	48.4	57
Hard tussock	65.3	64.5	54.0	51.3	53.9	58
Silver tussock	70.2	70.2	43.5	67.4	44.9	59

There were no significant differences in emergences of these three species when compared in this way. However, there were some large differences in emergence within each tussock species arising from different cover treatments. This is apparent in Table 3, but is shown in absolute values in Table 4, where mean numbers of seedlings per plot are given.

TABLE 4. *Numbers of tussock seedlings emerging per plot — Porter's Pass.*

COVER	Blue tussock	Hard tussock	Silver tussock	All species
Control	8.75	12.50	12.50	33.75
Clover	7.75	12.25	12.50	32.50
Fescue	7.25	9.75	12.00	29.00
Browntop	6.00	10.25	8.00	24.25
Fog	5.50	10.25	7.75	23.50
	N.S.	N.S.	LSD 3.50 (5%)	LSD 8.41 (1%) LSD 5.99 (5%)

The differences in seedling numbers amongst cover treatments is most marked in the means for the all-species grouping. Analysis of variance showed that emergence under browntop and fog for this group was significantly lower (at the 1% level) than for control. Emergences under white clover and chewings fescue were not significantly different from control.

Although the same general trend was apparent for the individual tussock species, there was greater variation in numbers amongst the plots and only with silver tussock were the differences significant. Here, as for the all-species grouping, emergence under browntop and fog was significantly lower than for control.

Because estimates or measurements of ground cover obtained from the various cover treatments were not complete before the first winter, it is not possible to relate the figures for tussock emergence directly to the ground cover achieved during the first growing season. Some indication of the relative covers may be obtained from the records in the spring of 1968, 10 months after sowing. These give the number of hits out of 100 measurements which struck cover vegetation in each plot. Mean values for the four replicates of each treatment in September 1968, were: control, 4; white clover, 6; chewings fescue, 44; browntop, 59; Yorkshire fog, 46.

Survival — The tussock seedlings were counted in December 1967 and in May 1968 to give figures for total emergence as shown in Table 4. There were some deaths between December and May and the numbers of deaths were deducted from total emergence to give survival figures for autumn 1968. Further counts of seedlings made in September 1968 and April 1969 showed the changes in proportions of seedlings surviving in the five cover treatments (Table 5).

TABLE 5. *Tussock seedling at successive countings — Porter's Pass (mean number per plot, all species grouped).*

COVER	Total emergence	Autumn 1968	Spring 1968	Autumn 1969
Control	33.7	23.2	14.5	8.5
Clover	32.5	23.0	15.0	7.7
Fescue	29.0	16.5	13.5	8.7
Browntop	24.2	14.7	14.0	12.2
Fog	23.5	16.0	13.7	10.2
	LSD 8.41 (1%) 5.99 (5%)	LSD 6.99 (1%) 4.99 (5%)	N.S.	N.S.

This table shows clearly the trend downward in numbers of tussock seedlings in all treatments and, in particular, the very marked fall in numbers in the control and white clover plots.

The effect of the relative changes in seedling numbers under different cover crops is shown in analysis of variance of each seedling count. Thus, as discussed earlier, total emergence during the first growing season was significantly lower under Yorkshire fog and browntop than under the control. This same relationship persisted in the counts for survival made in late autumn, but with the addition that tussock numbers under chewings fescue were then also significantly lower than for control.

However, by the spring of 1968 this difference had been lost and by the autumn of 1969 the trend was for highest persistence under the densest cover (Table 6).

TABLE 6. *Tussock emergence and survival in relation to cover treatment — Porter's Pass (mean per plot, all species grouped).*

	Emergence 1967–68	Survival 1969	% survival	% Hits cover 1969
Control	33.7	8.5	25.2	4
Clover	32.5	7.7	23.7	6
Fescue	29.0	8.7	30.0	40
Fog	23.5	10.2	43.4	41
Browntop	24.2	12.2	49.8	54

There were very wide differences in mean percentage survival as shown in Table 6, but very large variations occurred amongst figures for individual plots, and there were no statistically significant differences.

TABLE 7. *Seedling tussock losses — Porter's Pass — from emergence 1968 to autumn 1969 (mean number per plot).*

	Blue tussock	Hard tussock	Silver tussock	All tussock
Control	5.5	10.5	9.2	25.2
Clover	5.2	10.5	9.0	24.7
Fescue	6.0	8.0	6.2	20.2
Fog	3.7	5.0	4.5	13.2
Browntop	2.2	6.7	3.0	12.0

The details of the mean number of seedlings lost per plot for each species and cover combination are given in Table 7. This shows that the trends in losses were similar for each tussock species, but, again, the individual plot figures were too variable for satisfactory statistical interpretation.

The figures in Table 6 show a strong relationship between the percentage of hits on cover (or the percentage of hits on bare ground) and the number of tussock seedlings lost from each treatment. The correlation coefficient calculated for the percentage bare ground on each of the 20 plots and the percentage survival of all tussock gave a figure of $r = -0.608$ which is significant at the 1% level.

Over the trial as a whole the survival rates to the autumn of 1969, expressed as a percentage of emergence, were: blue tussock 35.5%, hard tussock 25.9% and silver tussock 39.3%. If survival is expressed as a percentage of viable seed sown then the figures are 20.2%, 15% and 23.3% respectively.

(b) *Craigieburn*

Emergence — The exceptionally heavy snow of 16 and 17 November 1967 which was followed by very rapid thaw caused severe surface wash and rill erosion on the Craigieburn site approximately three weeks after sowing. A rill approximately 6 in. deep and 8–12 in. wide developed throughout the length of two of the four replicates and, with accompanying surface washing of soil, effectively destroyed any chance of obtaining results from one half of the trial. Such severity of erosion on a relatively gentle slope (8°) was surprising. Results on the other two replicates were almost certainly affected by surface wash, but counts for emergence and for survival were made in the autumn of 1968 and the autumn of 1969. Total emergence for these two replicates is shown in Table 8.

TABLE 8. *Emergence of seedlings at Craigieburn.*

	No. emerged	% of sown	% of viable
Blue tussock	28	14.0	—
Hard tussock	54	27.0	28.4
Silver tussock	67	33.5	37.6

Notodanthonia setifolia has been omitted from the detailed results as emergence was again very low, with only eight seedlings emerging from 100 seeds. The seed of blue tussock was from a different source and was older than the seed used at Porter's Pass. Because of an oversight it was not tested for germination until 20 months after the Craigieburn sowing and the seed was then four years old. The mean germination was 14%. Although the viability at time of sowing cannot be determined, it is not likely to have exceeded the 62% recorded for the recently-harvested seed used at Porter's Pass. However, it was almost certainly more than the 14% recorded in 1969.

For hard tussock and silver tussock, emergence rated 49% and 64%, respectively, of that recorded at Porter's Pass. Because of the destruction of two replicates, low emergence in the remainder and uncertainty about the viability of blue tussock, no attempt has been made to test differences amongst tussock species within cover crops. The numbers of tussock seedlings emerging per plot, within species and cover categories are shown in Table 9.

TABLE 9. *Numbers of tussock seedlings emerging per plot — Craigieburn.*

COVER	Blue tussock	Hard tussock	Silver tussock	All tussock
Control	6.0	7.5	8.0	21.5
Clover	2.5	5.5	9.0	17.0
Fescue	2.0	4.5	6.5	13.0
Browntop	1.5	6.5	6.0	14.0
Fog	2.0	3.0	4.0	9.0
				N.S.

Despite the small number of samples available these figures do show a trend in relation to cover treatment similar to that recorded at Porter's Pass (Table 4). For the all-tussock grouping, highest emergence was recorded under control and lowest under Yorkshire fog. An analysis of variance for records for all-tussock failed to show any significant difference arising from cover treatment.

Survival — Previous trials at the Craigieburn site had shown that browntop was an aggressive invader when fertiliser was applied to bare subsoil. This was borne out by results in control plots which were given the fertiliser mixture, but no cover seeding. By the autumn of 1968, seven months after seeding, records of percentage hits on cover vegetation as a mean of two plots were as follows:

Control	Clover	Fescue	Fog	Browntop
52.0	40.0	64.0	72.5	82.5

The control plot had more cover than all treatments at Porter's Pass except browntop. Hits on browntop comprised 47 out of the 52 on control plots, 13 of the 40 on clover plots and 26 of the 64 on chewings fescue plots. The growth of browntop undoubtedly had a stabilising effect and severely limited the value of the control for comparing survival. There was, in fact, very little mortality in tussock seedlings between emergence and the autumn of 1969, as is illustrated by figures in Table 10.

TABLE 10. *Tussock emergence and survival in relation to cover treatment — Craigieburn (mean per plot for all species)*

	Emergence 1968	Survival 1969	% Survival	% Cover 1969
Control	21.5	21.0	97.7	54
Clover	17.0	13.0	76.5	41
Fescue	13.0	11.5	88.5	54
Browntop	14.4	13.5	96.4	85
Fog	9.0	8.0	88.9	59

The much higher survival than shown in Table 6 for Porter's Pass may be attributed to the better cover and gentler slope. Although the initial figures for emergence were considerably lower than at Porter's Pass, the numbers per plot at the end of the period were better for all treatments except Yorkshire fog.

There was very little difference in survivals amongst the individual tussock species. Thus, for the trial as a whole, survival as a percentage of emergence was: blue tussock 96, hard tussock 89 and silver tussock 88. Survival of hard tussock and silver tussock seedlings as a percentage of the viable seed sown was slightly better than at Porter's Pass, 25 and 33 compared with 15 and 23.

GROWTH OF SEEDLINGS

In the early autumn of 1968, erosion below the fence at Porter's Pass allowed hares to enter the plot and graze much of the cover vegetation and some of the seedling tussocks. This grazing affected the records of seedling heights made in the spring of 1968 but did not affect the records for tiller numbers. There was no grazing at Craigieburn.

At Porter's Pass, 11 months after sowing, the mean heights of plants were, blue tussock, 3.27 cm., hard tussock, 5.36 cm. and silver tussock, 5.81 cm. At Craigieburn, seven months after sowing, the mean heights were, 4.03 cm., 6.32 cm. and 6.27 cm. respectively. Moister soil conditions coupled with the absence of grazing could account for the greater size of the Craigieburn plants.

Tiller counts made at the same time also showed a trend for larger tussocks at Craigieburn (Table 11).

TABLE 11. *Number of tillers on young tussocks.*

	Blue tussock		Hard tussock		Silver tussock	
COVER	(a)	(b)	(a)	(b)	(a)	(b)
Browntop	6.2	5.5	2.7	3.4	3.2	4.0
Fog	8.2	10.2	3.4	3.2	3.9	5.4
Fescue	6.1	6.0	4.2	4.8	4.1	5.6
Clover	6.5	11.3	4.2	5.6	6.0	4.0
Control	13.5	9.4	6.7	6.8	8.6	8.9
Mean	8.6	9.2	4.1	5.0	5.2	5.6

(a) Porter's Pass, September 1968.
(b) Craigieburn, May 1968.

At Porter's Pass the ranking of tiller numbers from greatest number for blue tussock to smallest number for hard tussock was maintained under all cover treatments except chewings fescue. There was a markedly larger number of tillers in the control or no cover treatment than in the grass and clover treatments. This may be attributed principally to the lack of competition for fertiliser nitrogen from cover species. There was also little competition with tussock seedlings in the clover plots because of poor clover establishment (6% cover, 1969) but there, in the absence of fertiliser nitrogen, tussock tiller numbers were similar to those in the grass plots.

Mean numbers of tillers for each tussock species for the whole trial were slightly larger at Craigieburn than at Porter's Pass, but they were not consistently so in relation to cover treatment. In common with the Porter's Pass results, the ranking order for tiller numbers was from blue tussock greatest to hard tussock least for all cover treatments except one. The invasion of the clover and the control plots by browntop at Craigieburn appears to have lessened the beneficial effect on tiller numbers which was present in the absence of competition at Porter's Pass.

By the autumn of 1969 measurements showed that there were only slight changes in the heights and tiller numbers of most tussock seedlings. At Porter's Pass, the mean tiller numbers for blue, hard and silver tussocks respectively were, 8.8, 4.1, and 6.1, compared with 8.6, 4.1 and 5.2 in the previous spring. By contrast the figures for mean number of tillers for tussocks in the *control* plots had risen substantially for all three species, from 13.5 to 16.5 for blue tussock, 6.7 to 13.4 for hard tussock and from 8.6 to 15.1 for silver tussock. This was not, however, an indication of growth in all seedlings but was a reflection of the high natural culling of the smaller seedlings in the unprotected ground.

In May 1969 at Craigieburn too, the mean number of tillers had decreased, from 9.2 to 7.1 for blue tussock, 5.0 to 4.6 for hard tussock and 5.6 to 4.8 for silver tussock. On the clover and control plots the presence of much browntop cover had prevented frost heaving of the smaller tussocks and as a consequence figures for mean tiller numbers on these plots showed only a slight downward trend compared with the large increase at Porter's Pass.

CONCLUSIONS

The results of these trials were somewhat disappointing, particularly in the low seedling numbers, which were caused in part by storm damage. Increased replication could have helped to overcome this.

There seem to be no major differences amongst the three tussock species in their ability to germinate and emerge in the field. On the other hand, the poor emergence of *Notodanthonia setifolia* is worth further investigation.

Emergence of the tussocks was influenced apparently by the density of the other plant cover establishing at the same time. Tussock emergence generally decreased with increasing amounts of other plant cover.

The percentage of seedling tussocks surviving the action of frost-heaving and subsequent desiccation was also closely linked with the success of establishment of the cover species. Thus, survival varied inversely with the amount of bare ground in each plot. Although results did not enable firm conclusions to be drawn on the relative abilities of the tussock species to survive, there were indications that hard tussock seedlings were less able in this respect than blue or silver tussock.

Growth of the tussocks was very slow, even with fertiliser. Less competition for nutrients from cover species on control plots was reflected in greater tillering in tussocks, but against this increase in size must be balanced the lower survival rate on unprotected soil.

Most tussocks decreased in size during the second growing season. It is possible that although tussock seedlings establish under these conditions, they may not survive for long without additional fertiliser or with nitrogen from legumes. However, if there is merit in attempting to re-establish a many-layered vegetation, then the inclusion of tussock seeds in the mixture provides some hope of achieving this.

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