THE INFLUENCE OF FERTILISER AND GROUND COVER ON GROWTH AND SURVIVAL OF TUSSOCK SPECIES ON MOUNTAIN SUBSOILS

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SUMMARY: Seedlings of five native tussock species grown in the glasshouse on mountain subsoil showed outstanding responses to nitrogen and phosphorus fertiliser in combination. The most vigorous species was silver tussock but this produced less dry matter than an introduced grass, Yorkshire fog, grown on the same soil. Tussocks in general responded positively to applications of magnesium and potassium but growth was depressed by lime.

In field sowings at two sites under different vegetative covers tussock seedling survivals over a five summer period were very low. Improved survival in early years through protection by cover species appeared to be offset in later years by competition for nutrients from the same species. Best survival rates were shown by blue tussock and silver tussock.

INTRODUCTION

Experimental work in the montane and subalpine zones of New Zealand during the last 10 years has demonstrated clearly that, on subsoils and scree surfaces exposed by topsoil erosion, it is possible to establish a protective herbaceous cover of introduced plants in the one growing season. Major requirements for success are the use of the correct plant species and fertiliser and good fortune with the weather.

The costs of the treatment are high. Moreover, in the absence of maintenance fertiliser, there is usually a downward trend in the protective ability of the vegetation after the flush of growth in the first season. It has also been shown that for the most effective growth, indeed for satisfactory growth at all on some subsoils, a wide range of nutrients must be used (Dunbar and Adams 1972). In view of the initial and possibly continuing high costs, any factor which adds to the durability of the cover or reduces maintenance dressings of fertiliser will also increase the practical application of the technique. It is important to find answers to questions such as: How long must a soil surface be protected and stabilised before native plants can re-establish themselves in the community? Must there be a long period of succession from small annual herbs to tall growing perennial grasses, or can the process be shortened? Will the native tussock species grow and persist at fertility levels lower than those necessary for some of the exotic species? Do they need a similar range of nutrients?

There has been comparatively little work in study of the nutrient needs of indigenous tussock species. The effect of fertiliser and other factors of management on mature plants of a *Chionochloa* species have been studied by O'Connor and Powell (1963), and O'Connor (1963), while seedling responses of four *Chionochloa* species to soil and fertiliser treatment in a glasshouse experiment were reported by Molloy and Connor (1970). Morrison (1958) examined the response of seedlings of *Festuca novae-zelandiae* to varying fertiliser treatments in pots, and Scott (1970) compared relative growth rates of seven indigenous and five introduced grasses under several temperature and nutrient supply regimes.

This paper reports results of a glasshouse study of the response to added nutrients by five tussock species grown on a mountain subsoil and adds to information previously published on establishment and survival of tussock species in field sowings (Dunbar 1970).

MATERIALS AND METHODS

1. *Pot Experiment*

Design — Five native tussock species and one introduced grass, Yorkshire fog *(Holcus lanatus* L.), were grown in separate blocks of 32 pots, using a common soil, but with each block having five nutrient treatments applied in a 2^5 single replicate factorial design.

Soil — Soil material was brought to the glasshouse from an exposed subsoil of a high country yellow-brown earth at 975 m above sea level at Porter's Pass, Canterbury. Soil test data are given in Table 1. The soil was air dried and passed through a six millimetre sieve before potting in square section plastic pots having an exposed soil surface of approximately 120 cm². Each pot contained 670 g of air dried soil.

Nutrient treatments – The nutrients used and the rates and forms applied are shown in Table 2. Basal treatments of sulphur, copper, boron and molybdenum were given to all pots, while nitrogen, phosphorus, magnesium, potassium and lime were applied as factorial treatments. Lime was mixed throughout the soil, monocalcium phosphate and calcium sulphate were applied to the surface one centimetre as solids and remaining compounds were applied to the soil surface in solution.

TABLE 1. *Experimental Soil Material From Kaikouran Subsoil, Porter's Pass*

	pH	P (Truog)	Ca	Mg	K	Na	C.E.C.
				(Milli equivalents %)			
Soil Test	5.3	1	0.59	0.07	0.09	0.03	8.60
Rating	Mod. Acid	Very Low	Very Low	Very Low	Very Low	Very Low	Low

TABLE 2. *Rates and Forms of Nutrients in Pot Experiment*

Nutrient		Rate of Nutrient (kg/ha)	Compound
Factorial	N	83	Ammonium nitrate
	P	92	Monocalcium phosphate
	K	49	Potassium chloride
	Mg	30	Magnesium chloride
	Lime	950	Calcium carbonate
Basal	S	71	Calcium sulphate
	Cu	1.42	Cupric chloride
	B	0.86	Sodium tetraborate
	Mo	0.09	Sodium molybdate

Plant material – Plants of all species were grown from seed to establish four plants to each pot. The species of native tussock and the seed origins are shown in Table 3. Seed of native species was sown in late November-early December 1967 and plants were harvested in mid May 1968. Yorkshire fog seed was of the Massey Basyn cultivar. It was sown in late February 1968 and shoots were harvested in mid June 1968. Pots were watered regularly with de-ionised water to 70 percent of the water holding capacity of the soil by weight.

2. *Field Sowings*

At Porter's Pass, Canterbury, four tussock species were seeded into five cover treatments in the spring of 1967, the site being on an exposed Kaikouran subsoil at 975 m above sea level. The location of the trial site and a detailed description of the establishing of the experiment have been published earlier (Dunbar 1970).

At Black Birch in Marlborough a similar experiment was established in 1968, again on a Kaikouran subsoil but at 1430 m above sea level

TABLE 3. *Species and Seed Origins of Native Tussocks*

Species	Source
Hard tussock (*Festuca novae-zelandiae*)	Lincoln grown, ex Mackenzie Country, 670 m above sea level
Matthew's fescue (*F. matthewsii*)	Lincoln grown, ex Lindis Pass, 970 m above sea level
Blue tussock (*Poa colensoi*)	'Ben Ohau', Mackenzie Country, 490 m above sea level
Silver tussock (*P. laevis*)	Lake Lyndon, Porter's Pass, 850 m above sea level
Mountain danthonia (*Notodanthonia setifolia*)	Island Pass, Clarence River, 1370 m above sea level

on a north aspect, seven degree slope, with annual precipitation of approximately 1400 mm (Fig. 1). Soil test data for this site are given by Dunbar and Adams (1972). The soil was of similar low fertility to that at Porter's Pass. The technique of establishment was as described for

FIGURE 1. *Field trial site at 1430 m altitude, Black Birch, Marlborough*

Porter's Pass. There were some variations in design at Black Birch. The five cover treatments were, unsown, Chewings fescue *(Festuca rubra* L. ssp *commutata* Gaud.), browntop *(Agrostis tenuis* Sibth.), Yorkshire fog (low rate) and Yorkshire fog (high rate). The rate of seeding was based on one viable seed to 13 cm² for Yorkshire fog (low rate) and one viable seed to 6.5 cm² for remaining covers. The native species sown were as described here for the pot experiment, with the exception that Matthew's fescue *(Festuca matthewsii)* (Hack) Cheesem) was replaced by a strain of hard tussock *(Festuca novae-zelandiae* (Hack) Ckn.) collected from 1130 m above sea level in the upper Clarence River area. Basal fertiliser supplied nitrogen, phosphorus, potassium, magnesium, sulphur and calcium at same rates as for previous trials, but calcium-ammonium-nitrate replaced urea as the source of nitrogen. Five replicates of the trial were set down on 16 and 17 October 1968.

RESULTS AND DISCUSSION

1. *Growth of Tussock Species*

In the pot trial growth of all species was extremely poor except where both nitrogen and phosphorus had been applied. The effect of nitrogen and phosphorus treatments on tiller number and total shoot weight of the five tussock species and Yorkshire fog is shown in Table 4. The interaction effect was highly significant for all species. The response by the native species was similar to that previously recorded for Yorkshire fog on a range of mountain subsoils (Dunbar and Adams 1972). Figures in Table 4 show that in this trial the order of the response by silver tussock and Yorkshire fog was similar, even though the growing period for fog was approximately four weeks less than for the tussock species.

Because of the very poor growth in the absence of nitrogen and phosphorus the comparison of species performance under conditions of reasonable soil fertility was limited to the eight

TABLE 4. *The Effect of Nitrogen and Phosphorus on Tillering and Total Shoot Yield of Five Tussock Species and Yorkshire Fog*

(Dry weight in grams x 10⁻²)

	Hard tussock		Matthews fescue		Blue tussock		Silver tussock		Mtn danthonia		Yorkshire fog	
	Tillers	Dry wt	Tillers	Dry wt	Tillers	Dry wt	Tillers	Dry Wt	Tillers	Dry wt	Tillers	Dry wt
No N, No P	4	13	3	8	5	15	4	18	2	2	1	2
N, No P	3	8	2	4	3	3	3	10	1	1	1	1
No N, P	9	40	10	54	13	62	8	67	7	17	5	59
N, P	22	151	24	254	42	354	25	409	29	160	18	495
5% L.S.D.	3	30	2	39	5	62	5	39	4	27	1	28
Significance of interaction	**	**	**	**	**	**	**	**	**	**	**	**

pots of each species which had been given both nitrogen and phosphorus treatments. Some large differences were apparent. Figures for the nitrogen plus phosphorus treatments in Table 4 show that, in mean tillers per plant, blue tussock (*Poa colensoi* Hook.f.) far surpassed the other native species. However, silver tussock (*Poa laevis* R.Br.) gave the highest per pot yield of both shoot and root, although not significantly larger than for blue tussock (Table 5). There were no significant differences in the mean root to shoot ratios for the native species. The proportions of root to shoot appear to be considerably higher than those recorded by Scott (1970).

TABLE 5. *Root and Shoot Yield of Tussock Species with Basal N/P Fertiliser*

	Root	Shoot	R/S Ratio (%)
Silver tussock	379	409	89
Blue tussock	289	354	81
Matthews fescue	248	255	87
Mountain danthonia	121	161	70
Hard tussock	130	151	83
L.S.D. 5%	94	81	

2. *Response to Magnesium, Potassium and Lime*

The very strong nitrogen-phosphorus interaction also meant that the effect of magnesium, potash and lime treatments could be examined with validity only on those pots with basal nitrogen and phosphorus (i.e., eight pots for each species). Although main effects of these treatments were substantial on several parameters for each species, few effects were statistically significant. The trend throughout was similar to that observed in previous trials on different subsoils — in general there was a positive response to magnesium and potassium and a depressive effect of lime on both root and shoot growth. An exception in this trial was blue tussock, for which the main effect of magnesium was to depress both shoot and root growth.

Over the trial as a whole the effect of the magnesium, potassium and lime treatments was to amplify the trends shown by the individual species, with the depressive effect of lime most strongly pronounced over several parameters (Table 6). Potassium and magnesium treatments both had marked positive effects on the proportion of root to shoot, without decreasing total shoot dry weight, which has some relevance to the revegetation of unstable slopes.

TABLE 6. *Response to Magnesium, Potash and Lime Treatments by all Tussock Species*

(Figures are differences resulting from presence or absence of treatment. Dry weight in grams x 10^{-2})

	Tiller Number	Shoot Dry wt	Root Dry wt	Total Dry wt	Root Shoot (%)
Magnesium	−0.7	19	56	74	15*
Potassium	2.6	49	66*	116*	11
Lime	−5.0*	−75**	−44	−118*	5
5% L.S.D.	4.2	52	59	104	12
Trial Mean	28.5	266	233	499	81

3. *Survival in Field Trials*

Early results published from the Porter's Pass field experiment (Dunbar 1970) showed that at the end of an 18-month period from emergence, the survival of tussock seedlings was best in those plots with the most sown ground cover remaining. Figures for tussock and cover records after five summers as shown in Table 7 confirm the early observation to some degree but indicate that competition from cover has also had an effect. Whereas in 1969 percentage survival was highest in the most dense cover, under browntop, by 1972 survival was best in Yorkshire fog which had good initial cover but declined more rapidly than browntop.

TABLE 7. *Survival of Sown Tussocks in Different Covers at Porter's Pass*

Type of Cover	Tussock Emergence 1967	Tussock Survival 1972	Percentage Survival	% hits cover 1972
Browntop	24.2	3.2	13.2	42
Fog	23.5	6.0	25.5	12
Fescue	29.0	4.0	13.8	28
Clover	32.5	1.5	4.6	2
Unsown	33.7	1.7	5.2	3
L.S.D. 5%	6.0	4.4		

At Black Birch the establishment of sown cover seems to have had no beneficial effect on eventual survival of accompanying tussocks. Figures for emergence and survival of tussocks were generally lower than at Porter's Pass, but best survival in 1973 was clearly in the plots where no cover was sown (Table 8). Although the mean number of tussock plants remaining in each plot is very small, the figure of 2.6 tussocks for "unsown" treatment is significantly larger than for the Chewings fescue and the two Yorkshire fog treatments.

TABLE 8. *Survival of Sown Tussocks in Different Covers at Black Birch*

Type of Cover	Tussock Emergence 1968	Tussock Survival 1973	Percentage Survival	% hits cover 1973
Browntop	19.4	1.6	8.2	18
Fog (High)	18.2	1.2	6.6	2
Fescue	16.4	0.4	2.4	15
Fog (Low)	14.2	0.8	5.6	3
Unsown	17.8	2.6	14.6	6
L.S.D. 5%	9.2	1.3		

Figure 2 compares the changes in sown cover with the decrease in tussock survivals over four seasons at Black Birch, emphasising that on this gently sloping site the longer retention of cover did not benefit tussock survival. In fact it appears that cover species may be strongly competitive with the tussocks for nutrients. The figures for silver tussock plants, which comprise more than half of the total of all surviving tussocks, illustrate this point. At post-emergence counts in 1969 there were 33 silver tussock seedlings on the one unsown treatment and 122 silver tussocks on the four treatments with sown cover. At the end of the fifth growing season, in 1973, nine tussocks survived on unsown and nine on all cover treatments, the comparison being 27 percent

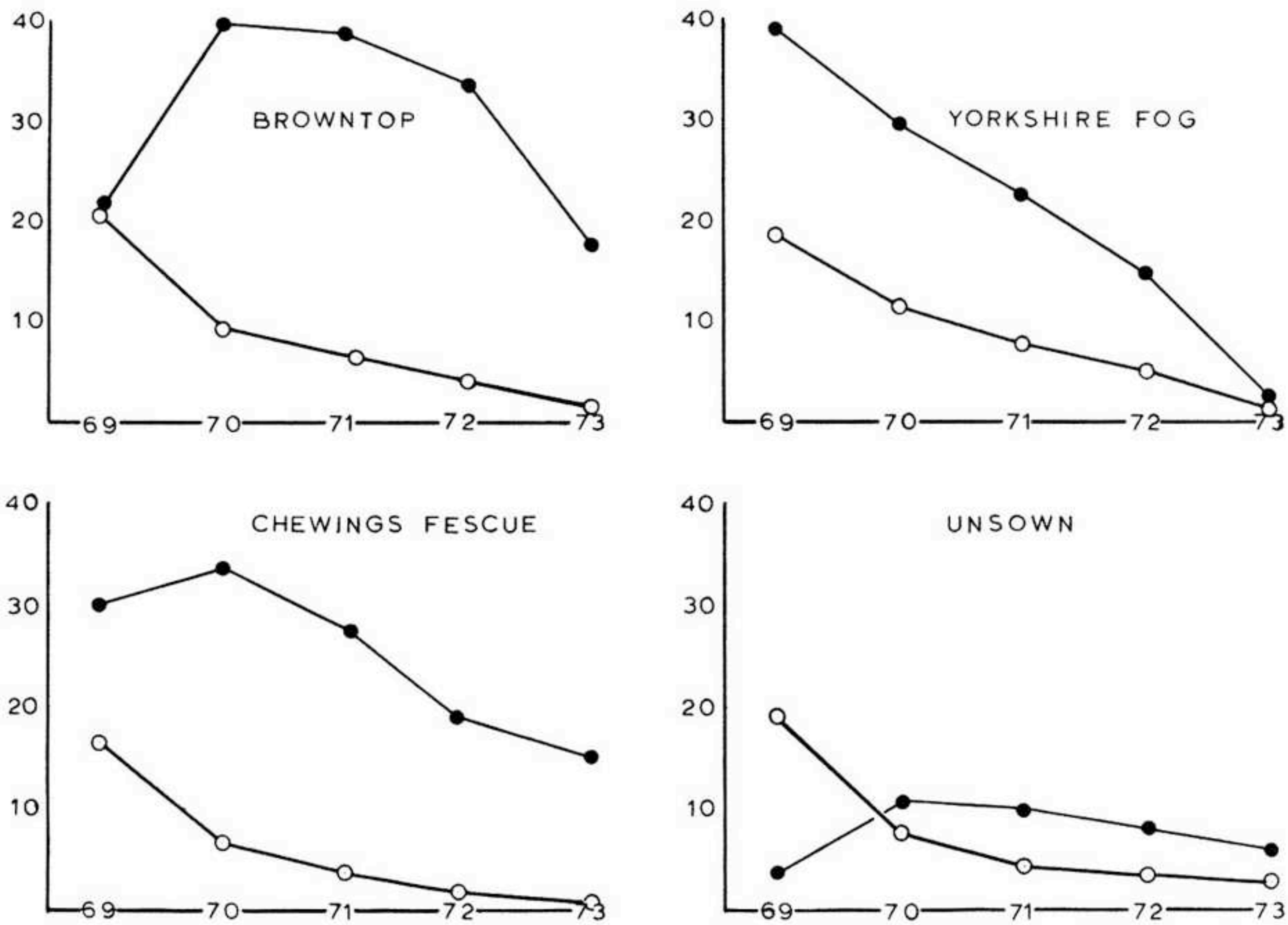

FIGURE 2. *Comparisons over a five-summer period, between the number of hits on cover from four sown treatments (●), and the number of tussock seedlings surviving within those treatments (○).*

survival on unsown and 7 percent on cover. In further comparison of vigour of these seedlings, the mean number of tillers of seedlings in unsown was in excess of 15 while mean height of tallest leaf was 75 mm. The mean number of tillers for the tussocks in cover was 1.7 and mean height was 33 mm.

These effects were present in this experiment where the sole application of fertiliser was at the establishment stage. It is possible that a different trend might have been apparent in the presence of further fertiliser applications in the second or third years.

TABLE 9. *Survival of Tussock Seedlings at Two Sites as a percentage of emergence*

Tussock Species	Porter's Pass (1967-72)	Black Birch (1968-73)
Blue	14.2	31.8
Hard (Holbrook)	9.5	1.8
Hard (Clarence)	Not sown	5.0
Silver (Lyndon)	11.8	11.7

With regard to the individual tussock species, it is difficult to draw clear conclusions as to their respective abilities to survive once seedlings have emerged. At both Porter's Pass and Black Birch emergence of mountain danthonia was negligible, and no importance could be attached to survival figures. For blue, hard and silver tussocks the survival as a percentage of emerged seedlings is shown in Table 9, and blue tussock appears to have greater survival ability than the other two species. However, since only 22 blue tussock seedlings had emerged originally at Black Birch, more work with a larger number of seedlings is needed as a base for sound conclusion. Moreover, within each of the species of tussocks used in these studies, there could well be wide differences in adaptation and survival at a particular site, depending upon the origins of the seed. Differences in origin should also be recognised as a source of possible variation in the response to fertiliser in pot or field trials.

CONCLUSIONS

All five tussock species in the pot study showed high capacity for seedling response to nitrogen and phosphorus applications on low fertility subsoil, although the ability of the most responsive species, silver tussock, was not as great as Yorkshire fog.

The study suggests that in the absence of applied nitrogen and phosphorus several native species are able to grow better than Yorkshire fog, but this growth would still be insufficient to enable plants to withstand frost lift destruction on exposed subsoils.

Although nitrogen and phosphorus proved to be the major nutrient requirements for good growth, application of magnesium and potassium gave good responses with all species except blue tussock, whereas lime proved detrimental to all species.

Within the limits of the species tested in these experiments, silver tussock and blue tussock showed most promise for use in high altitude revegetation, but severe competition from exotic grasses in a mixed sowing may restrict their usefulness. The most profitable extension of this work appears to be in more detailed study of the range of silver tussock and blue tussock types and the use of a high proportion of native grass seeds in revegetation mixtures.

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