An experimental study of the factors limiting plant growth in upper Teesdale

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AN EXPERIMENTAL STUDY OF THE FACTORS LIMITING PLANT GROWTH IN UPPER TEESDALE

by

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CONTENTS

LIST OF TABLES

1. INTRODUCTION

Upper Teesdale in the northern Pennines of England (Grid Ref. NY 8129) has long been famous for its rich and peculiar flora, (Backhouse and Backhouse, 1843; Valentine et.al., 1965), which includes pre-alpine, alpine, arctic-alpine and sub-arctic plants (Pigott, 1956), see Table 1. These will be collectively referred to as the Teesdale Rarities. Most of these plants are to be found, some in great abundance, between the 300 and 600 metre contours, which in an area at a latitude of 54°40'N close to the Atlantic coast of Europe is indeed remarkable.

The Teesdale Rarities are best interpreted as relict fragments of a flora which was widespread in Britain some 10 to 12 thousand years ago (Godwin and Walters, 1967). That these 'fragments' have persisted in the area throughout the period is now well authenticated (Turner and Hewetson, 1970), a period of great climatic change during which the area in question has been transformed from an open periglacial landscape into one dominated by forest and subsequently by blanket peat.

The contemporary climate of the high western boundary of Upper Teesdale is marginally sub-arctic (Manley, 1942), but the climate of the main area in which the Teesdale Rarities are found is much less extreme, and must differ but little from that of other large stretches of the Pennines. Why then is this rich assemblage of species present only in Upper Teesdale?

Recent work has shown that some of the vegetation types which contain large numbers of Teesdale Rarities, although closed in terms of ground cover, are characterised by low standing crop and productivity (Bellamy et.al., 1969; Marshall, 1971).

The vegetation of the bulk of these low production, closed communities falls within the compass of the two phytosociological categories *Tofieldietalia* and *Seslerio-mesobromion* sensu, Jones (1973), and are, in the main, found in the proximity of the extensive areas of sugar limestone which are a unique feature of the fells of the Upper Teesdale region, (Johnson, 1971).

There seems little doubt that the skeletal soils which have developed over the friable sugar limestone, and are designated as calcareous syrosems (Shimwell, 1969), could have provided the open refugia necessary for survival of the 'rarities' throughout the post glacial period. The observations of Pigott (1956) concerning refugia in alpine spruce forest and that of Siebert (1968) on similar refugia in pre-alpine pine forest in Bavaria are of relevance here; as are those of Turner and Hewetson (1970) who concluded that even during the period of their maximum development, the woodlands of Upper Teesdale were never closed.

Vegetation referable to both the above categories described for Upper Teesdale are widespread at both higher and lower altitudes in other areas of the Pennines, the only feature unique to the area under study being the presence of the sugar limestone.

Is the presence of the Teesdale Rarities simply due to their long term survival on and around the sugar limestone, or do the calcareous syrosems possess some other feature limiting the growth of vegetation, and thus provide unique conditions for the development and maintenance of the unique Teesdale communities?

This thesis presents results of a study of some of the factors which may limit the productivity of the Teesdale communities. The study centres around a comparison of the performance of selected species both in the field in Upper Teesdale, at Tarn Moor in Cumbria and when transplanted to the Durham University Botanic Gardens, (Grid Ref. NZ 2741).

Tarn Moor (Grid Ref. NY 6707) supports a diverse vegetation first described by Holdgate (1955), which includes areas of Tofieldietalia and Seslerio-mesobromion developed in close juxtaposition below springs and seepage lines associated with a complex of boundaries between glacial drift and the underlying carboniferous limestone. Many of these vegetation units are very open with a total plant cover of less than 50%, and thus appear ideal sites in which the Teesdale Rarities could thrive.

Tarn Moor lies only 17 miles to the S.W. of Upper Teesdale, yet its flora includes only two of the Teesdale assemblage, namely Primula farinosa in some abundance, and Plantago maritima which is very rare. The Tarn Moor site lies at around 300m above sea level, and has a much more lowland character than Upper Teesdale. The Tofieldeitalia type vegetation being dominated by Schoenus nigricans, a species absent from Upper Teesdale, and containing abundant Eriophorum latifolium, which is very rare in Upper Teesdale. Similarly the Seslerio mesobromion of Tarn Moor is rich in lowland species with Festuca rubra and F. ovina being the dominant grasses almost to the exclusion of Sesleria over large areas. Added to this is the fact that Molinia caerulea is an abundant member of the Tarn Moor vegetation, while it is, surprisingly, somewhat of a rarity in the Teesdale area under investigation.

Nevertheless, there are on Tarn Moor large areas of open calcareous flushland, and close cropped grass sward developed on skeletal soils which would appear to be ideal habitats for the growth of the Teesdale Rarities.

There is one further striking difference between the two areas mentioned above, and this is the presence of an ore bearing metamorphic limestone on Widdybank Fell. Johnson et. al. (1971) noted that the unique relict flora of Teesdale exists for the most part on soils developed from this metalliferous rock.. Marshall (1971) carried out some analysis of soils from Widdybank Fell and concluded that the levels of Zn and Pb were high, although he presented no comparitive data to confirm this. Jeffrey and Pigott (1973) showed that the addition of phosphate to vegetation rich in certain of the Teesdale Rarities brought about an increase in the abundance of certain grass species with a consequent reduction in the abundance of Kobresia simpliciuscula

As a result of all these observations it was decided to carry out a series of experiments designed to throw light on the relative importance of soil and climate to the continuing existence of the rare plants of Teesdale.

The first two sections of the thesis involve comparative studies of the vegetative performance of selected species, both in situ in field transplants, and in pot culture. The third section is concerned with similar comparitive measurements on communities in situ in Upper Teesdale, the microclimates of which had been altered by enclosure within free standing cold frames.

As many of the experiments are, in the main, a logical progression from one to the next they are reported as such, preliminary discussion of the results of each experiment being included before proceeding to describe and present the results from the next.

2. EXPERIMENTAL DESIGN AND RESULTS

A. SITE SELECTION

Early in 1973 areas supporting uniform stands of vegetation with more than 95% ground cover and referable to associations of the Tofieldietalia and Seslerio Mesobromio sensu Jones (1973) were selected by eye on Widdybank Fell in Upper Teesdale; also near the Sunbiggin Tarn outflow stream on Tarn Moors. For brevity the communities will be referred to as 'flush' and grassland and the sites as 'Teesdale' and 'Sunbiggin' throughout the text. The vegetation of each site was described using the standard field methods of the Zurich Montpetier School of phytocociology (Braun Blanquet, 1961). Results of the survey are presented in the form of constancy tables in Table 1.

Apart from the abundance of the Teesdale Rarities in the one, the only striking difference pointing to the more lowland character of the Sunbiggin area is the abundance of Schoenus nigricans in the 'flushes'.

B. 1st EXPERIMENT

AIM

The first question to be asked was, are the communities at Sunbiggin more productive than their counterparts in Teesdale?

METHOD

It was decided to use species which were abundant in the community at both sites as phytometers to ascertain the differences, if any. The species selected were Carex panicea and C. lepidocarpa both of which are abundant in the 'flush' communities at each site, and Sesleria caerulea as one of the

Table 1(a) Constancy tables from the vegetation at Teesdale (T) and Sunbiggin (S)

Tofieldietalia

	T	S
Agrostis canina	II	
Anthoxanthum odoratum	III	IV
Bellis perennis	II	
Breutelia chrysocoma		II
Bryum pseudotriquetrum	III	III
Cardamine pratensis	I	
Campylium stellatum		III
Carex capillaris	III	
Carex echinata	I	
Carex hostiana		III
Carex lepidocarpa	V	V
Carex nigra		IV
Carex panicea	V	V
Carex pulicaris	IV	III
Chara spp.		II
Cratoneuron commutatum		II
Cratoneuron filicinum		III
Ctenidium molluscum	IV	IV
Deschampsia caespitosa	I	
Drepanocladus revolvens		IV
Eleocharis quenquiflora	III	
Epilobium palustre		II
Equisetum palustre		III
Equisetum variegatum	IV	
Eriophorum angustifolium	III	IV
Eriophorum latifolium		IV
Euphrasia micrantha	II	
Festuca ovina		IV
Festuca rubra	IV	
Holcus lanatus		III
Juncus acutiflorus		II
Juncus alpinoarticulatus	II	
Juncus articulatus	IV	IV
Juncus squarrosus	I	
Juncus triglumis	III	
Kobresia simpliciuscula	V	
Leontodon hispidus	I	
Linum catharticum	III	
Lophocolea bidentata	IV	IV
Molinia caerulea		IV
Nostoc spp.		II
Pedicularis palustris		IV
Pellia epiphylla	II	
Philonotis calcarea		I
Philonotis fontana	III	
Pinguicula vulgaris	III	III
Plantago lanceolata	II	
Plantago maritima	IV	
Potentilla erecta	II	IV

	T	S
Preissia quadrata	III	
Primula farinosa	V	II
Prunella vulgaris	II	
Rhacomitrium lanuginosum	III	
Riccardia multifida	III	II
Riccardia pinguis		III
Rumex acetosella	I	
Sagina nodosa	II	
Schoenus nigricans		V
Scorpidium scorpioides		III
Selaginella selaginoides	IV	IV
Succisa pratensis		IV
Taraxacum spectabile		II
Thymus drucei	I	
Tofieldia pusilla	V	

------ Teesdale rarieties

Table 1(b) Constancy tables from the vegetation at Teesdale (T) and Sunbiggin (S)

Seslerio-Mesobromion

	T	S
Achillea millefolium		III
Agrostis tenuis	II	III
Aira spp.		I
Alchemilla xanthochlora		I
Anthoxanthum odoratum	II	
Bellis perennis	III	IV
Briza media		III
Calluna vulgaris	II	II
Campanula rotundifolia	II	II
Carex capillaris	IV	
Carex caryophyllea	III	III
Carex flacca		III
Carex panicea	V	V
Carex pulicaris	II	
Certraria islandica	II	
Cirsium arvense		II
Cladonia arbuscula	III	
Conopodium majus		II
Cornicularia aculeata	II	
Ctenidium molluscum		I
Deschampsia caespitosa	I	
Ditrichum flexicaule	III	
Euphrasia micrantha		II
Festuca ovina	III	V
Festuca rubra		IV
Galium boreale	II	
Galium hercynicum		II
Galium saxatile	II	
Galium sterneri	III	
Galium verum		II
Gentiana verna	IV	
Gentianella amarella	III	I
Helianthemum chamaecistus	II	
Helictotrichon pratense		III
Hieracium pilosella	II	
Holcus lanatus		III
Hylocomium splendens	II	
Juncus articulatus	II	
Kobresia simpliciuscula	IV	
Leontodon hispidus		III
Linum catharticum	III	IV
Lotus corniculatus		III
Luzula multiflora		III
Luzula sylvatica	I	
Pinguicula vulgaris	III	
Plantago lanceolata	I	IV
Plantago maritima	IV	
Pleurozium schreberi	II	II
Polygala amara	II	
Polytrichum commune	I	
Potentilla erecta	IV	IV
Poterium sanguisorba		II
Preissia quadrata	II	
Primula farinosa	V	III
Primula vulgaris		I
Prunella vulgaris	II	III
Pseudoscleropodium purum		I
Ranunculus acris		I
Rhacomitrium lanuginosum	III	
Rhytidiadelphus loreus	II	
Selaginella selaginoides	V	IV
Sesleria caerulea	V	IV
Taraxacum officinale		III
Thymus drucei	III	III
Tortella tortuosa	I	
Trifolium pratense		III
Trifolium repens	I	II
Viola canina	II	

----- Teesdale rarieties

grassland dominants. Their performances were measured using the single species increment cropping technique (Marshall, 1971).

At monthly intervals throughout the growing period of 1973 samples of no less than 19 undamaged individuals were randomly collected from each site by measuring along compass bearings using a table of random numbers. Selection of undamaged (ungrazed) individuals was by visual inspection. At the laboratory, the above ground parts of the plants were separated from the roots, the latter were discarded (except in the case of the final cropping) and the former were dried to constant weight at 98°C.

RESULTS

The complete data are presented in Table AP9 and summarised in Figs. 1 - 3, where the 95% confidence limits are shown by the vertical bars.

DISCUSSION

The dual standing crop peaks for both the Carices are readily explained by the fact that they are biennial perennials, each shoot appearing above ground in one season and overwintering before maturation in the second year, similar double peaks for C. panicea were obtained by Reiley (1967). The complex form of the curves however, does not hide the fact that both species show significantly higher above ground biomass at Sunbiggin than they do at Teesdale. The results for Sesleria, although less clear, still indicate significantly better performance at Sunbiggin.

If the results for performance of those phytometers reflects the performance of the total community there is little doubt that the higher standing crop and productivity of the Sunbiggin communities could exclude the Teesdale

Rarities from the latter site, see Bellamy et.al. (1969). As no study of the total biomass of the communities was carried out it is impossible to take this argument any further. There is, however, no reason to dispute the fact that for the phytometers used, growth conditions at Sunbiggin are significantly better than those pertaining in Teesdale. These differences could be due to one, or a combination of all three of the following:

1. genetical differences between the plants present in the two areas;
2. climatic differences;
3. edaphic differences.

C. 2nd EXPERIMENT

AIM

To ascertain what, if any, are the differences in the edaphic conditions between the two sites.

METHOD

In August, at the end of the 1973 growing season, six quadrats were selected at random, (method as above) within each of the study sites. A soil core of diameter 2 cm was removed from the centre of each using a large cork borer as an auger. Each core was individually wrapped in polythene for transportation to the laboratory, where they were analysed for the following cations: Al, Ca, Cd, Cu, Fe, Mg, Mn, Na, Pb, and Zn, as well as for P. See Appendix A for the extraction and analytical procedures.

RESULTS

Results of the analysis are given in detail in Table AP3 and are summarised in Table 3. Comparison of the analytical results shows:

1. that the 'flush' soils of Teesdale are significantly richer in exchangeable Na, K, Mn, Fe, Zn, Cd, Pb and P than their Sunbiggin

counterparts, and

2. that the grassland soils of Teesdale are significantly richer in exchangeable Ca, Zn, Pb, and P, and significantly poorer in exchangeable Mg and K than those of Sunbiggin.

DISCUSSION

The presence of significantly larger amounts of heavy metals in the Teesdale situation might at least in part account for the lower performance of the phytometers: the observations of Marshall (1971) and of Pigott and Jefferies (1973) are of relevance here, and will be fully discussed in section 3.

D. <u>EXPERIMENT 3</u>

AIM

To determine whether the edaphic difference reported above are reflected in the chemistry of the phytometers. In view of the amount of analytical work required, only one of the phytometers, <u>Carex panicea,</u> was studied in this way.

METHOD

All material of <u>Carex panicea</u> from the final harvest, described above, was retained after drying to constant weight, the roots having been washed free of all adhering soil prior to drying. The roots and live leaves were then separated and analysed for the full range of elements studied above. (see Appendix A for methods).

RESULTS

The results are presented in full in Table AP4 and are summarised in

Table 2 Concentration of some elements in leaves and roots of *Carex panicea*[1] from Teesdale and Sunbiggin (mg/g.d.wt.)

in leaves

	Teesdale	Sunbiggin	s.o.d.
Mg	.563	.753	****
Al	.154	.173	NS
K	10.05	10.72	**
Ca	5.03	4.76	NS
Fe	.688	.444	***
Mn	.234	.354	****
Zn	.146	.071	****
Cd	.0012	.0007	****
Pb	.114	.053	**
P	.599	.633	*

in roots

	Teesdale	Sunbiggin	s.o.d.
Mg	.463	.663	****
Al	1.002	1.451	*
K	3.29	4.25	****
Ca	9.93	5.53	**
Fe	10.648	7.132	**
Mn	1.179	.708	****
Zn	.477	.163	****
Cd	.0056	.0015	****
Pb	.161	.071	***
P	.326	.461	****

s.o.d. = significance of difference - see Appendix B

[1] material collected from *Tofieldietalia* vegetation (see Table AP4 for details)

Table 3 Exchangeable cations and phosphorus in soil cores collected in Teesdale and Sunbiggin (mg/g.d.wt.)

	Teesdale	Sunbiggin	s.o.d.
	Tofieldietalia		
Na	.457	.197	***
Mg	1.030	.755	NS
Al	.058	.025	NS
K	1.585	.292	***
Ca	80.485	44.535	***
Mn	.237	.104	***
Fe	.178	.058	**
Cu	.0055	.005	NS
Zn	.376	.012	***
Cd	.008	.001	***
Pb	.119	.015	***
[1] P	.008	.004	**
	Seslerio-Mesobromion		
Na	.210	.258	NS
Mg	.408	1.169	***
Al	.111	.115	NS
K	.835	1.158	**
Ca	76.335	41.210	***
Mn	.100	.460	NS
Fe	.139	.065	NS
Cu	.0046	.0049	NS
Zn	.176	.0148	***
Cd	.0056	.0022	***
Pb	.181	.0108	***
[1] P	.012	.009	**

[1] Extracted with 0.5 M Na HCO_3

s.o.d. significance of difference - see Appendix B

(see Table AP1 for details)

Table 2. Comparison of the mean values for each element using the Students t-test indicates that both the roots and leaves of the Teesdale plants are significantly richer in Fe, Zn, Cd and Pb, and significantly poorer in Mg, K and P than in roots and leaves of those growing at Sunbiggin.

DISCUSSION

The results for the metals are in accordance with the edaphic difference demonstrated above for the flush soils, but P, K and Mg show the highest concentration in plants growing on the soil with lower exchangeable amounts of these elements.

E. EXPERIMENT 4

AIM

To gain data in an attempt to differentiate between the effects of climate and soil.

METHOD

Instead of trying to overcome the problems of setting up, maintaining, and monitoring transplant experiments at the two field locations (vandalism could have been a problem at Sunbiggin), it was decided to locate them in the University Botanic Garden in Durham City.

The plants selected for study were Carex lepidocarpa, and C. panicea, as they are abundant in both localities, Schoenus nigricans, and Eriophorum latifolium, which are present only at Sunbiggin, and Tofieldia pusilla which is one of of the Teesdale Rarities. In order to minimise damage to the Teesdale communities all plants except Tofieldia were collected from Sunbiggin.

Table 4 Total cations, total and extractable P, pH of *Tofieldietalia* soils used in pot culture experiment (mg/g.d.wt.)

	Teesdale	Sunbiggin	s.o.d.
Na	.361	.087	***
Mg	1.420	1.660	***
Al	27.000	10.633	***
K	1.170	1.119	NS
Ca	11.000	5.426	***
Mn	1.202	.454	***
Fe	26.022	8.655	***
Cu	.022	.012	***
Zn	1.294	.098	***
Cd	.015	.002	***
Pb	.616	.057	***
Tot.P	.425	.148	***
Ex.P	.008	.005	***
pH	6.7	7.2	***

s.o.d. significance of difference - see Appendix B

(see Table AP2 for details)

Collection was made in late January 1974, the plants being washed free of all soil before being layed on damp filter paper. Using a table of random numbers, 15 individuals of each species were selected, and each planted singly in a 4 inch plastic pot containing flush soil from Teesdale. The remaining 15 of each species was similarly planted in 4 inch pots containing flush soil from Sunbiggin, and then the total lengths of the live leaves in all the pots were recorded. The pots were then placed in a cold frame for one month, before being embedded in open gravel on a flat surface clear of all obstacles in the Botanic Garden. The pots were arranged in a regularly spaced mosaic. The plants were watered everyday with rainwater from a butt, thus supplementing the natural rainfall throughout the study. A further two months were allowed to elapse before measurement of leaf length, at fortnightly intervals, was begun.

At the end of the experiment the plants were harvested, the roots being carefully removed from the soil. The live leaf and root material were separated, washed and dried to constant weight prior to extraction and analysis.(for methods see Appendix A)

RESULTS OF GROWTH MEASUREMENT

The complete results are presented in Table AP10 and are summarised in Figs 4 - 9, where the log of the geometric means for each species has been plotted against time. The reasons for these transormations are given in Appendix B. The y-axes have been adjusted so that both curves start at the origin, this simplifies visual comparisons. Only 4 points on the T.pusilla and 3 points on one of the C. lepidocarpa curves satisfy the requirements of linearity.

The responses, though varied all indicate agreement in one respect, in no case do the plants show a slower rate of growth on the Teesdale soils.

Table 5 Clay minerals in Teesdale* and Sunbiggin *Tofieldietalia* soil used in pot experiments.

Teesdale	Sunbiggin
Chlorite or Vermiculite	Montmorillonite
Illite	Chlorite
Kaolinite	Illite
Boehmite	Kaolinite
Quartz (34%)	Quartz (64%)

* the clay minerals in these samples are highly degraded.

Table 6 Some physical characteristics of Tofieldietalia soil used in pot experiment. Moisture and texture expressed as % air dry wt. Loss on ignition as % of soil dried at 100°C.

	Teesdale	Sunbiggin	s.o.d.
Moisture	4.06	1.47	***
l.o.i.	27.78	8.62	***
Sand	71.36	76.22	NS
Silt	26.79	16.56	NS
Clay	1.85	7.22	NS

s.o.d. significance of difference - see Appendix B for details

In fact from the regression coefficients (coefficient of x in the equations) it is clear that in all the five cases the rate of growth was marginally better on the Teesdale soils. Overall comparison of the regression coefficients using the students t-test on the difference of the sums shows the difference to be significant with $P < 0.01$. From these results it would appear safe to conclude that once the main phase of growth has started, the Teesdale soil forms a marginally better growth medium for all the species studied, and that soil alone cannot account for the low productivity at Teesdale. There is some evidence that during the early part of the year, the plants did not grow better on the Teesdale soil, this will be discussed in section 5.

RESULTS OF CHEMICAL ANALYSIS

The full analytical results reported in Table AP5, are summarised. Tables 7 and 8..

The data for the leaf analysis shows few significant trends, although the metal content of plants on Teesdale soil is generally higher; however, data from the root analysis is more definite. In all cases Zn, Cd, and Pb shows higher concentration in the roots of the plants growing in the Teesdale soil, and in four cases out of five, Fe shows the same effect.

DISCUSSION

Comparison of the relevant soil data, Tables 3 and 4, shows that the Sunbiggin soils used in the experiment have significantly less total Pb, Cd, Zn, Cu, Fe, Mn, Ca than the Teesdale soil, the same is true for both total, and exchangeable P, while the reverse is true for Mg (although exchangeable Mg is higher in the Teesdale flush soils, Table 3) and there

Table 7 Concentration of some elements in leaves and roots of plants grown in pots (mg/g.d.wt.)

a) In live leaves

	C.panicea			C.lepidocarpa			E.latifolium			Schoenus nigricans			Tofieldia pusilla		
	Ts	Ss	s.o.d.	Ts	Ss	s.o.d.	Ts	Ss	s.o.d.	Ts	Ss	s.o.d.	Ts	Ss	s.o.d.
Mg	1.57	1.01	***	1.16	.90	*	1.23	.99	NS	1.36	1.70	NS	1.07	1.15	NS
Al	.21	.32	NS	1.21	1.15	NS	.35	.28	NS	.61	.12	*	1.22	1.15	NS
K	12.47	14.23	NS	12.11	10.60	NS	9.92	9.17	NS	6.38	10.46	*	6.67	7.50	NS
Ca	7.48	6.15	NS	6.41	4.46	NS	7.49	6.65	NS	8.37	9.69	NS	16.55	14.97	NS
Fe	.30	.41	NS	1.11	1.22	NS	.41	.38	NS	.77	.27	*	1.30	1.18	NS
Zn	.170	.092	*	.107	.046	NS	.137	.066	NS	.109	.057	NS	.126	.252	*
Cd	.0036	.0015	***	.0025	.0007	**	.0009	.0013	NS	.0019	.0012	NS	.0049	.0027	**
Pb	.0146	.0201	NS	.0471	.0338	NS	.0139	.0078	NS	.0250	.0067	NS	.0341	.0145	NS
P	.996	1.047	NS	1.147	.762	NS	.986	.932	NS	.933	.850	NS	1.509	1.178	NS

b) In live roots

Mg	1.07	1.19	*	1.50	1.79	***	1.14	1.31	NS	.70	.83	NS	1.20	1.39	NS
Al	3.25	2.59	NS	2.77	3.94	*	5.36	3.03	***	4.84	2.52	**	7.46	4.46	**
K	4.28	3.63	NS	4.44	3.55	**	4.44	5.35	**	1.71	3.60	**	3.39	4.44	*
Ca	4.14	4.22	NS	3.26	3.92	NS	5.60	4.51	NS	15.67	11.82	**	7.68	6.75	NS
Fe	5.48	4.20	*	3.17	3.68	NS	4.47	2.72	**	5.02	2.83	**	5.72	3.95	*
Zn	.323	.078	****	.209	.056	***	.376	.069	****	.290	.079	**	.554	.152	***
Cd	.0109	.0024	****	.0103	.0019	****	.0141	.0016	****	.0048	.0014	**	.0104	.0026	***
Pb	.0946	.0416	***	.0983	.0335	***	.1186	.0229	****	.1320	.0261	***	.1622	.0899	**
P	1.736	.944	***	.710	.946	NS	.809	.764	NS	.487	.589	NS	1.416	1.188	NS

s.o.d. significance of difference - see Appendix B

(see Table AP5 for details)

Table 8 Average concentration of elements in leaves and roots of all the pot experiment species. (mg/g.d.wt.)

in leaves

	Ts	Ss	s.o.d.
Mg	1.29	1.10	**
Al	.68	.60	NS
K	10.08	10.66	NS
Ca	9.09	7.83	NS
Fe	.73	.68	NS
Zn	.132	.093	NS
Cd	.0027	.0014	***
Pb	.0264	.0177	NS
P	1.094	.942	*

in roots

Mg	1.16	1.34	*
Al	4.47	3.27	**
K	3.86	4.13	NS
Ca	6.39	5.75	NS
Fe	4.66	3.49	**
Zn	.337	.081	****
Cd	.0106	.0020	****
Pb	.1162	.0399	****
P	1.047	.886	NS

s.o.d. significance of difference - see Appendix B

Figures derived from results in Table 7

is no significant difference for total K concentration. (Again, however the exchangeable K is much higher at Teesdale Table 3).

It must be concluded therefore that in the higher temperature of the lowland station at Durham, considerable amounts of the potentially antagonistic heavy metals pass onto the root system of the plants. There are indications that they may be localised there, in that they do not pass into the leaves. Whatever the mechanism, the enhanced concentrations of heavy metals appear to have no drastic effect on the uptake of P or on the performance of the plants studied in that climate. It would appear that in the warmer climate of the experimental garden and altered edaphic conditions in the pots, a range of plants can overcome the problems, if any, of the higher levels of heavy metals present in the Teesdale soils, allowing sufficient uptake of nutrients for growth.

F. EXPERIMENT 5

AIM

To further investigate the effect of climate and soil using a single phytometer of genetically pure stock, namely Spring Barley var Julia recommended by the Welsh Plant Breeding Station. Owing to the almost unlimited supply of seed it was decided to place one set in the field at Teesdale where at least some protection was afforded by siting the experimental plot within the confines of the National Nature Reserve. The other set was maintained in the Durham Botanic Garden.

METHOD

Twenty-five pots were filled with flush soil collected as before from Teesdale, the same number being filled with flush soil from Sunbiggin.

Table 9(a) Concentration of some elements in leaves of barley grown in pots (mg/g.d.wt.)

	Teesdale soil			Sunbiggin soil		
	Teesdale	Durham	s.o.d.	Teesdale	Durham	s.o.d.
Mg	1.44	1.25	**	1.40	1.22	*
Al	.86	.46	*	.63	.50	NS
K	13.57	13.29	NS	16.12	15.03	NS
Ca	9.90	9.46	NS	8.67	8.49	NS
Fe	.99	.74	NS	.83	.74	NS
Zn	.300	.130	**	.184	.071	NS
Cd	.0040	.0009	***	.0009	.0005	NS
Pb	.0488	.0237	***	.0225	.0152	NS
P	1.269	1.421	NS	1.196	1.037	NS

s.o.d. significance of difference - see Appendix B

(see Table AP.6 for full details)

Table 9(b) Total amount of some elements in the leaves of barley at the end of the experiment (mg/pot)

	Teesdale soil		Sunbiggin soil	
	Teesdale	Durham	Teesdale	Durham
Mg	.070	.088	.061	.058
K	.662	.984	.709	.718
Ca	.483	.700	.381	.405
P	.061	.105	.052	.049
Al	.041	.033	.027	.023
Fl	.048	.054	.036	.035
Zn	.014	.010	.008	.004
Cd	.0002	.0001	.00004	.00003
Pb	.0023	.0017	.0009	.0007

9(b) is derived from 9a and mean values in Table AP.11, therefore statistical tests were not possible

Three barley seeds were planted in each pot, and after ecesis the weaker two were removed. Half the pots containing each type of soil were placed in loose gravel in a regular mosaic at the botanic garden, the other half, prepared in the same manner, were located at Widdybank Fell in Upper Teesdale.

At the end of the growing period, all the leaves from each pot were harvested, and dried to constant weight before extraction and analysis.

RESULTS

The full biomass results are presented in Table AP 11, the chemical data in Table 9.

Performance was compared using the mean final dry weights in each crop. Analysis of variance revealed no significant difference between the growth of barley on the two soils at Teesdale. In contrast the growth was significantly better on the Teesdale soil than on the Sunbiggin soil in the warmer climate of Durham. The overall differences of climate between the two stations are summarised in Figs. 9 - 11 and Table 10. The data were obtained from the standard meteorological office recording stations at Widdybank Fell and Durham University.

DISCUSSION

Comparison of the phytochemistry (see Table 9A)is of interest. Barley growing on the two soils, both at Teesdale and Durham show similar results to the previous pot experiments, with the plants on the Teesdale soils having higher concentrations of P, Pb, Cd, Zn, Al, Fe and Ca than those on the Sunbiggin soils, only K showing the reverse trend. The results are

Table 10

Summary climatic data from Durham and Teesdale during the barley pot experiment: June, July, August.

	Durham	Teesdale
Temperature (^{o}C)		
Highest max. recorded	26.9	23.9
Lowest min. recorded	3.5	-3.3
Average max.	18.9	15.3
Average min.	10.1	7.8
No of days with temp. $\geqslant 5^{o}$C	88	79
Humidity (%)		
Max. recorded	97	97
Min. recorded	58	50
Average	81.3	82
Rainfall (mm)		
No of days with 0.2 mm or more	12	5
No of days with 1.0 mm or more	20	18
No of days with 5.0 mm or more	8	21
Greatest fall in 24 h.	33.7	55.9
Total rainfall over June, July, August	171.7	331.7

See Figs. 9-11 for details

again in keeping with the overall differences between the soils shown in Tables 3 and 4.

Between site comparison is perhaps more revealing. On the Teesdale soils the concentrations of Al, Zn, Cd, K and Pb are all significantly higher in the leaves of the barley grown at Teesdale when compared with those grown at Durham. In contrast plants grown on the Sunbiggin soils in the two sites show only small differences in the concentration of these elements none of which are significant.

G. EXPERIMENT 6 (a)

AIM

Manipulation of the In-situ climate of the Upper Teesdale Vegetation.

METHOD

A trial experiment was carried out in the summer of 1973. Five uniform areas of grassland, selected with the permission of the Nature Conservancy, were covered with commercial cold frames made of corrugated plastic, the ends being closed with sheets of flat transparent plastic. The experiment was begun in early June, and terminated at the end of August. The cold frames were removed and a photograph taken to record the results. The total above ground vegetation was then harvested from one 20 x 20 cm quadrat in the centre of each cold frame plot, and from a similar area 1 metre to the side of each frame. The harvests were separately dried before being extracted and analysed for a range of elements. (The results for K have, unfortunately, been lost).

Table 11 Results of 1973 cold frame experiment on Seslerio-Mesobromion vegetation in Teesdale. Concentration of elements in vegetation inside and outside the cold frame. (mosses excluded) (mg/g.d.wt.)

	Outside	Inside	s.o.d.
Mg	.733	.887	**
Al	.195	.054	***
Ca	6.250	7.180	*
Mn	.132	.130	NS
Fe	.460	.160	**
Zn	.132	.093	NS
Cd	.002	.001	**
Pb	.090	.041	NS
P	.761	.753	NS

s.o.d. significance of difference - see Appendix B

(see Table AP7 for details)

RESULTS

The full chemical results are shown in Table A P7, and are summarised in Table 11.

Although no measurements were made, it is evident from plate 2 that the vegetation had grown considerably more robust within the confines of the cold frame. Comparison of the chemistry of the two sets of crops shows that in all cases the concentration of heavy metals is less in the plants growing within the frames, the differences for Cd, Fe and Al reaching significance. In contrast both Mg and Ca show the reverse trend while the concentration of P are almost equal in the vegetation from both treatments.

DISCUSSION

Although only an indication, it would appear that one of the effects of altering (warming) the climate was to cause a reduction in the uptake, or a dilution of the heavy metals and Al, whilst the reverse was true for Ca and Mg. On the basis of the success of this experiment it was decided to repeat it in a more elaborate form.

EXPERIMENT 6 (b)

AIM

Further study of the effects of manipulating the <u>in-situ</u> environment of the Teesdale communities. Extensive survey of the Widdybank Fell experimental area, had previously indicated the existence of two contrasting types of both 'flush' and grassland vegetation. Field analysis showed that although they were floristically similar, and all had 100% plant cover, one type in each case appeared to be less "productive" than the other. An explanation was sought, and a tentative one found in the fact that the apparently low production communities were situated much closer to metalliferous deposits than the apparently more productive communities. It was therefore decided to tentatively label the two types of 'metalalliferous' and non-metalliferous, and to study how the different facies of the two communities responded to climatic manipulation using further cold frame experiments.

METHOD

The four experimental sites were chosen early in April 1974, and cold frames 1' x 4' x 6' were erected well within the boundaries of each. For the design of the cold frames see Plates 3-5. The top of each cold frame was covered with transparent polythene sheeting, but the sides were only protected with open nylon net in order to allow free circulation of air, and to avoid the development of excessively high temperatures and humidity. Adjacent to each frame an equal area was staked out and protected from grazing by the erection of a nylon net barrier.

In order to gain some measure of how much these frames effected the climate near the ground, two pairs of recording thermohydrographs were intercalibrated. One of each pair was placed inside one of the cold frames, and the other of each pair was placed in a standard Stevenson's Screen located adjacent to the frame. The two frames selected for climatic monitoring were those which appeared from their location on the fell to be the least similar as far as their natural microclimate was concerned. See Plates 3A and 4B.

In order to compare growth throughout the summer, sampling was started on 1st May and continued over eight fortnightly sampling periods. Sampling was completed by the 21st August. In view of the limitations of size, and time available, it was calculated that 6 quadrats, each $1dm^2$ were the maximum that could be harvested on each occasion. These were located by the use of random numbers, but no area, in whole or in part, was cropped more than once.

Table 12 Concentration of some elements in Tofieldietalia vegetation (excluding mosses) at the end of the 1974 cold frame experiment (mg/g.d.wt.)

	Metalliferous			Non-metalliferous		
	uncov.	cover	s.o.d.	uncov.	cover	s.o.d.
Mg	.601	.780	****	.861	.947	*
Al	.077	.089	NS	.062	.047	NS
K	10.00	10.50	NS	9.77	10.14	NS
Ca	6.45	6.80	NS	3.76	3.53	NS
Fe	.148	.173	***	.154	.145	NS
Mn	.163	.149	NS	.321	.318	NS
Zn	.142	.146	NS	.075	.067	NS
Cd	.0020	.0018	NS	.0010	.0009	NS
Pb	.0154	.0170	NS	.0087	.0111	NS
P	.656	.649	NS	.605	.575	NS

s.o.d. significance of difference - see Appendix B

(see Table AP8 for details)

Table 13 Concentration of some elements in Seslerio-Mesobromion vegetation (excluding mosses) at the end of the 1974 cold frame experiment (mg/g.d.wt.)

	Metalliferous			Non-metalliferous		
	uncov.	cover.	s.o.d.	uncov.	cover.	s.o.d.
Mg	.942	.870	NS	.760	.881	NS
Al	.170	.122	***	.077	.059	NS
K	13.46	11.50	****	13.57	12.91	NS
Ca	5.78	5.96	NS	4.99	5.58	NS
Fe	.617	.335	****	.180	.169	NS
Mn	.177	.124	*	.154	.171	NS
Zn	.124	.086	****	.070	.065	NS
Cd	.0019	.0011	****	.0012	.0011	NS
Pb	.0230	.0417	****	.0194	.0115	**
P	.753	.651	*	.788	.700	*

s.o.d. significance of difference - see Appendix B

(see Table AP8 for details)

The vegetation was cropped to the soil surface. The vegetation from each quadrat was placed into a separate labelled polythene bag, and returned to the laboratory where dead material and bryophytes were discarded. From all the grassland plots, Sesleria caerulea, Festuca ovina and Carex panicea were sorted, and each weighed separately after drying. From all 'flush' plots Carex panicea was sorted and treated in the same way. At every time period the remaining plant material from each harvest was bulked, dried and weighed, this is referred to as the remainder.

The final sampling on August 21st consisted of 12 (flush) or 18 (grassland), 1 dm^2 plots harvested and treated in the same way. 18 replicates of grassland were taken in view of the lower standing crop of this vegetation. After weighing, the plant material was bulked, wet digested, and analysed for the full range of chemicals studied above. At the end of the experiment twelve 2 cm diameter soil cores were removed for chemical analysis.

RESULTS

Full details of the results are presented in Tables AP12 and 13, and are summarised in Tables 12-14 and in Figs. 12-17. The climatic data (Figs 18-21, and Table 15) indicates that the cold frames had their main affect on the maximum temperatures reached with little effect on the lower temperatures. The same is true of humidity, however the effect on humidity was not great.

The covers caused an increase in growth in all cases, but as the covers were designed to only slightly modify the climate the effect on growth is not apparent in the photographs (Plates 5A-8A). This had been anticipated and was the reason for carefully monitoring growth by weighing certain parts of the vegetation. The covers appeared to have a greater effect on the

Table 14 Exchangeable elements in soil cores collected from the sites of the second cold frame experiment (mg/g.d.wt.)

	in *Tofieldietalia* soil			in *Seslerio-Mesobromion* soil		
	metal	non-metal	s.o.d.	metal	non-metal	s.o.d.
Mg	.0529	.1125	****	.0515	.0635	**
Al	.0068	.0154	**	.0084	.0067	NS
K	.0562	.0765	*	.0633	.0546	NS
Ca	9.88	3.55	****	9.96	10.0	NS
Fe	.0129	.0440	NS	.0121	.0189	NS
Mn	.1029	.1933	***	.0657	.0508	***
Zn	.1570	.0401	****	.0231	.0161	**
Pb	.1342	.0468	****	.1741	.0413	**
[1]P	.0165	.0182	NS	.0154	.0125	*

s.o.d. significance of difference - see Appendix B

(see Table AP3 for details)

[1] extracted with 0.5 M Na HCO_3

vegetation of metaliferous sites, because it is only on these sites that the increases caused by the cover reach statistical significance(Table 18). The cold frames appeared to have little effect in the concentration of minerals in the flush sites (Table 12), in contrast to the metaliferous grassland site, where 8 of the ten changes reach statistical significance. Both the growth and chemistry results will be fully discussed in the next section.

Table 15

Summary microclimatic data from the Tofieldietalia non-metalliferous site and the Seslerio-Mesobromion metalliferous site during the period 18 June - 21 August of the field experiment.

	in Tofieldiet. non-metallif site		in Ses-Mes. metalliferous site	
Temperature (^{o}C)	uncov.	cover	uncov.	cover
Highest max. record	20	33	20	29
Lowest min.record	0	-2	2.5	-1
Average max.	13.9	19.6	13.1	19.8
Average min.	8.1	7.7	8.7	6.6
No of days with temp $\geq 5^{o}$C	63	59	63	48
Humidity (%)				
Lowest min.record	32	32	39	38
Highest max.record	92	87	77	79
Average min.	56	50	51	50
Average max.	75	80	74	66
Rainfall (mm)				
No of days with 0.2 mm or more	14			
No of days with 1.0 mm or more	14			
No of days with 5.0 mm or more	11			
Greatest fall in 24 h.	23.1			
Total rainfall from 18 June - 21 August	167.3			

(see Figs 18-21 for details)

3. DISCUSSION

Some discussion has already been presented in the previous section in order to explain the reasonings behind the various experiments. Some of these points will be reiterated below so that the various lines of discussion and conclusions can be presented as clearly as possible.

The analysis of soils and vegetation from Teesdale and Sunbiggin were intended to indicate the extent of any phytogeochemical differences between the two areas. Differences in the exchangeable cation content of soils from the two localities were established for both 'flush' and 'grassland' soils (Table 3), and estimation of the total cation content in soils used for the pot experiments substantiates the field data for 'flush' soil. (Table 4). Soil analysis indicates that the 'flush soil' soil from Teesdale is more fertile than that from Sunbiggin with exchangeable Mg, K, and Ca, as well as P all being higher in the former soil (Table 3). Examination of the metal contents (Tables 3 and 4) shows that for the most part, these are also more concentrated in the soils from Teesdale.

In general, then, there are both more nutrients and more heavy metals in the soils from Teesdale; a greater bulk of the soil from Sunbiggin being occupied by quartz (Table 5). Field material of C. panicea was collected for chemical analysis from flushes at both sites; the results (Table 2) show that the higher levels of 'nutrients' Ca, Mg, K and P, present in the 'flush soils' at Teesdale were not reflected in the leaf tissue analysis, nor, with the exception of Ca, in the root tissue analysis. In contrast, the heavy metals Fe, Cd, Zn, Pb, and Mn, were more concentrated in the leaves of Teesdale material and with the exception of Mn, the same was true of root tissue. Thus the higher levels of 'nutrients' in the Teesdale soils were not reflected by high concentrations in the tissues of C. panicea but the heavy metals were.

The possibility therefore arises, that a large proportion of the exchangeable nutrients in the Teesdale soil are simply unavailable to plants for purely edaphic reasons, in which case the low growth rates of some species in Teesdale as compared with their growth at Sunbiggin (fig. 1,2 & 3) could be accounted for simply by the colder climate and the lack of available cutrients (c.f. exchangeable nutrients).

The pot experiments were designed to gain information regarding performance of species on the soils from the two localities under identical climatic conditions. Results were plotted in logarithmic form so that any exponential growth phases would give linear plots, which could then be treated as simple regressions. The y - axis has been adjusted so that each pair of lines starts at the same point, thus making visual comparison easier (Fig. 4 - 8). It can be seen from the slopes and regression coefficients that in all cases growth during the summer was better on Teesdale soil. The overall difference between the regression coefficients of the two sets of soil is statistically significant ($p < 0.01$).

The plants used in pot experiments were selected randomly, therefore the mean starting value for each pair was about the same, however the intercepts of the regression equations show that at the start of the summer season the plants in Sunbiggin soil were somewhat larger than their counterparts in Teesdale soil. (See also detailed data Tables A P10). No detailed measurements were made whilst the plants were becoming established during the period before May, but the facts indicate that they did grow marginally better on Sunbiggin soil prior to the main growing season. This may have been due simply to the fact that the Teesdale soil was 'colder', loss on ignition (which results at least in part from organic matter) and moisture content would support this suggestion (Table 6).

The tolerance ranges of the two Carex species (Jermy and Tutin 1968) give no indication as to why they should have grown better in the Teesdale soil; indeed the sensitivity of C. lepidocarpa to aluminium (Clymo, 1962) suggests that this species might not be expected to grow as well in this soil (Table 4). If closed communities are examined in sites where gradients of pH exist, E.latifolium, S. nigricans, and T. pusilla are always found in the more alkaline situations, however the pH of the Sunbiggin soil (pH 7.3) was considerably higher than that of the Teesdale soil (pH 6.7).

The growth curves (Figs. 4 - 8) have been constructed from mean measurements of the surviving species and do not therefore reflect mortality. In most cases mortality was very low, however this was not so for Schoenus growing in Teesdale soil, where only 4 of the plants survived, compared with 13 of 15 growing in Sunbiggin soil (Table AP10). This is unlikely to have resulted simply from drying up, as the Teesdale soil appeared to have a higher moisture content (Tables 5 and 6). It has been suggested that Schoenus is also sensitive to Aluminium (Sparling 1967) which is another possible reason for the initial failure of this species on the Teesdale soil.

From the above observations it is clear that what little is known concerning the environmental tolerances of plants used in the pot experiments gives no clue as to why they should have grown better on the Teesdale soil. Therefore, it is possible that in the milder growth conditions of Durham the plants were able to take advantage of the more fertile Teesdale soil.

Comparison of field experiments with pot experiments has many obvious pitfalls, however, with this cautionary note in mind it is possible to examine chemical differences in the tissues of C. panicea resulting from the two soils when grown in pots in Durham, and compare these with differences in chemical content of field grown plants. Once again the concentration of metals was higher in the plants grown in Teesdale soil, reflecting its metaliferous nature, but Mg. K and P showed distinct differences from the field grown material. It was mentioned above that concentrations of these elements was significantly higher in both were roots and leaves of Sunbiggin plants than in plants from Teesdale, and thus did not reflect the higher nutrient status of flush soil from the latter area (Table 2). By contrast, in the Durham grown material only one of these 'nutrients' was significantly higher in plants on the Sunbiggin soil and this was Mg in the roots, also the significantly higher level of P in the roots of plants, grown on Teesdale soil is particularly noteworthy (Table 7). The summary of all the plants used in the Durham pot experiment (Table 8) shows that these general trends were true of all the species.

Evidence from the preceding experiments suggested that given identical conditions the growth rate of plants grown on Teesdale soil might be higher than those in the soil from Sunbiggin, it was also noted that under circumstances of the pot experiment the concentration of elements in the plants on Teesdale soil reflected the higher fertility of this soil. At this point therefore the argument could be presented that there is no edaphic reason why vegetation at Teesdale should not have a productivity higher than at Sunbiggin, and that the low productivity of Teesdale vegetation must be due to climate. However, the problem then arises as to why the rare species do not grow in the numerous other nearby locations where the climate is similar to that of Teesdale.

The first indication of a possible answer to this problem was obtained from the barley experiment. Because barley seed is readily available it was convenient to carry out comparisons of growth on the flush soils from Sunbiggin and Teesdale in a mild climate (Durham), and in a cold climate (Teesdale). The biomass results are shown in Table AP11, and the chemical composition in Table 9a. The concentration of elements in the leaves of barley declines throughout the growing season (Lundegardh, 1951; Goodall and Gregory 1947), therefore considering that performance on the two soils was estimated simply by harvesting the total crop from each pot at the end of the season, it was also convenient to calculate the total amount of each element taken into the leaves; these are shown in table 9b. From table AP11 it can be seen that there was no significant difference in leaf weight on the two soils in the cold climate, but in the warmer climate the average leaf weight per pot of Teesdale soil was nearly double the weight produced on pots of Sunbiggin soil. There was very little difference in the amount of 'nutrients' in the leaves of barley from either location when it was grown on Sunbiggin soil but the leaves of plants grown on Teesdale soil contained a much greater quantity when grown in Durham (Table 9.b).

Thus both the growth and nutrient content of barley reflected the greater fertility (and greater metal content) of the Teesdale soil, but results also suggest that this greater growth potential is not realised in the colder climate. This is competely consistent with the results of the other pot experiments, where it was observed that the intercepts in the regression equations indicate that any growth during the early part of the year (prior to regular measurements being taken) was, if anything better on the Sunbiggin soil. If the greater fertility of the Teesdale soil is not manifested in colder conditions it is reasonable to conclude that the low productivity of the Teesdale soils results from a combination of climate and soil, especially if the soil at Teesdale is 'colder'. However, we are again presented with the quandary that there is nothing peculiar about a soil being 'cold', in contrast the Teesdale flora is unique.

The comparisons of teesdale with Sunbiggin help to create a clearer picture of the extent to which the Teesdale vegetation and soil are unusual, however, it had been apparent from the outset of this research programme that results of microclimate manipulation at Teesdale would probably offer greater insite into the problem.

The 1973 experiment involved a very simple cold frame which increased growth of the 'grassland' vegetation on a metaliferous soil (Plate 4), confirming the results of Marshal (1971), who also used a simple completely closed frame. The concentration of elements in the above ground vegetation outside and inside the frame shows one feature very pertinent to the Teesdale situation. The uptake of 'nutrient' elements by vegetation beneath the frame appears to have more or less matched the increase in growth so that there was no reduction of concentration of 'nutrients' in the above ground tissues; by contrast the concentration of all the metals was lower in the higher productivity vegetation beneath the frame. The results of this experiment provided the first evidence, albeit circumstantial, implicating high metal concentrations with low productivity. Further examination of table 9 is worthwhile at this point. It can be seen in 9 (a) that there was little difference in the <u>total</u>

Table16 The effect of climate on the element concentrations in Barley leaves, illustrated by expressing the concentrations in leaves from warmer climate (Durham) as a ratio of those in leaves from cooler climate (Teesdale)

	Teesdale soil		Sunbiggin soil	
	mg Durham / mg Teesdale	rank of ratio	mg Durham / mg Teesdale	rank of ratio
Mg	.83	6	.87	6
Al	.53	4	.58	3
K	.98	7	.93	8
Ca	.96	8	.98	9
Fe	.75	5	.89	7
Zn	.43	2	.39	1
Cd	.23	1	.56	2
Pb	.49	3	.68	4
P	1.12	9	.86	5
Biomass ratio	.649		.918	

1. The ranking indicate the relative "effective dilution" of the element.
2. The biomass ratio is the average biomass per pot in Teesdale divided by the same at Durham.

(figures derived from Table 9a)

metal content of the leaves of barley at either location on either soil; in contrast the metal concentration in the leaves was lower in Teesdale on both soils, highly significantly so on the Teesdale one. These results suggest that unlike the nutrients, the uptake of metals did not match the increased growth.

The 1974 cold frame experiements were carried out on both flush and grassland sites, and utilised a cold frame which was designed not to raise the temperature too high (unlike the previous experiement and that of Marshal, 1971). Furthermore cold frames were placed on low productivity (metalliferous) as well as high productivity vegetation. The growth of the "remainder" (the total biomass excluding mosses and other ones measured) on the uncovered sites was in fact higher on the non-metalliferous sites as anticipated (Table 18). However it is interesting to note on the grassland site both S. caerulea and F. ovina had higher growth rates on the metalliferous site.

The effect of the covers was to raise the growth rate of all the vegetation measured, but the fact which is of greater relevance is that these differences reached a level of statistical significance only on the metalliferous sites (Table 18). The effect of covers on both metalliferous sites is especially noteworthy with respect to the 'remainder' of the herbaceous vegetation (76 % of the total). Thus it appears reasonable to conclude that raising the temperature slightly improves growth on metalliferous soils more than on non-metalliferous ones; in which case we can make a statement of the converse: that cold temperatures exacerbate the effect of growth reduction on heavy metal soils.

The effect of covers was somewhat less on the metalliferous 'flush' sites than on the metalliferous 'grassland' site, as might be expected considering the wetness of the former and the dryness of the latter.

Table 17(a) Summary table of ratios of element concentration in vegetation from inside and outside the cold frame of the first and second field experiment

	Metal Sesl. 73		Metal Sesl. 74		Non-metal Sesl. 74		Metal Tof. 74		Non-metal Tof. 74	
	conc. inside / conc. outside	Rank	conc. inside / conc. outside	Rank	conc. inside / conc. outside	Rank	conc. inside / conc. outside	Rank	conc. inside / conc. outside	Rank
Mg	1.210	9	.655	5	.856	5	1.157	9	1.120	9
Al	.277	1	.625	4	.500	2	1.049	5	.792	1
K	-	10	.848	8	.936	10	1.094	7	1.027	8
Ca	1.149	8	.864	9	.865	6	1.054	6	.907	4
Fe	.348	2	.732	6	.587	3	1.179	10	.974	6
Mn	.985	6	.527	1	.877	7	.829	1	1.026	7
Zn	.705	5	.598	3	.853	4	1.028	4	.893	2
Cd	.500	4	.579	2	.917	9	.900	2.	.900	3
Pb	.456	3	1.662	10	.400	1	1.104	8	1.276	10
P	.989	7	.768	7	.893	8	.989	3	.950	5
Growth ratios			.490		.677		.570		.894	

cont/

Table 17(b)

1. Figures are ratios of concentration inside the cold frame with respect to the concentration outside. (Derived from Tables 11, 12 and 13)

2. The ranking indicates the relative 'effective dilution' of the element,

3. The growth ratio is the value of b for total biomass outside the frame with respect to the value for b inside. (The values for b are derived from data in Tables AP12 and AP13)

(Climatic data summary Table 15). These differences must, at least in part be responsible for the fact that the aggregate improvement in growth rates caused by the cover on the metalliferous grassland site was x2.1, compared with x1.8 on 'flush' sites (aggregate derived from 6 values of metalliferous sites in Table 18). Examination of the chemistry of the vegetation shows that just as the effect of covers on growth rates was greatest on the metalliferous grassland vegetation, so the effect on the chemistry was also greatest on this site; note the levels of significance reached on this site (Table 13) compared with all other sites (Tables 12 and 13). With a few exceptions, the concentration of elements is lower in the covered vegetation, presumably due to the uptake in these cases not quite matching the increased growth. In the light of the foregoing discussion it would be valuable to know if certain elements are affected more than others when temperature induced growth improvement takes place. Data from the various experiments can yield information on this point, provided allowance is made for the fact that some 'dilution' will result from the fact that the plants are growing more. As this 'dilution' is the same for all elements the effect of cover on the different elements can be seen by simply dividing the concentration obtained in the warmer climate, with the concentration in the cooler one. This ratio expresses the extent to which the dilution, resulting from increased growth, was (when it will be $\geqslant 1$) or was not (<1) compensated by the increased growth. This ratio is called the 'effective dilution' in Tables 16 and 17, where figures for all the experiments involving temperature differences are shown; the 'effective dilution' for each element has also been ranked, with 1 as the greatest 'effective dilution'.

In Table 19 the result of averaging the 'effective dilution' for each element is presented. It is at once apparent that the metals are

Table 18 Growth rates recorded in second cold frame experiment

(see Figures 12-17 for details)

Tofieldietalia

Plant Material	Soil type	b uncov	b cover	s.o.d.
C. panicea	metal	.00285	.00398	NS
C. panicea	non-metal	.00296	.00298	NS
Remainder sp.	metal	.00393	.00791	***
Remainder sp.	non-metal	.00474	.00563	NS

Seslerio-Mesobromion

Plant Material	Soil type	b uncov	b cover	s.o.d.
S. caerulea	metal	.00223	.00344	NS
S. caerulea	non-metal	.00186	.00539	NS
F. ovina	metal	.00262	.00482	*
F. ovina	non-metal	.00166	.00263	NS
C. panicea	metal	.00142	.00423	*
C. panicea	non-metal	.00567	.00621	NS
Remainder sp.	metal	.00302	.00647	***
Remainder sp.	non-metal	.00409	.00540	NS

s.o.d. significance of difference - see Appendix B

(derived from data in Tables AP12 and AP13, and illustrated in Figs. 12-17) generally more affected than 'macro-nutrients'. The order is not consistent throughout all the experiments, therefore it was decided to test concordance of the ranks from different experiments, and the results of this test are also shown in Table 19. The null hypothesis is that there is no concordance between the rankings, and that the order of 'effective dilutions' is purely fortuitous. The χ^2 figure indicates that there is almost only 1 chance in 1000 that such a degree of concordance could have occurred by chance, therefore the null hypothesis can be rejected with confidence. It appears then that Aluminium and Zinc concentrations in the aerial vegetation are reduced most by temperature induced growth increase, with Calcium and Potassium being reduced least; in general the concentration of metals is reduced more than the concentration of 'nutrients'.

From the evidence presented above there appears to be little doubt that the growth of vegetation on the metalliferous soils of Widdybank Fell is lower than vegetation on the non-metalliferous soils, and that a rise in temperature of only a few degrees is sufficient for the problems of the metalliferous soils to be overcome and differences eliminated (The average b value for all uncovered vegetation on metalliferous soil is 0.16 and 0.021 for uncovered vegetation on non-metalliferous soil; the respective values for covered vegetation are 0.03 for metalliferous, and 0.028 for non-metalliferous soil: from Table 18). Also by inference, that the reduction of the concentration of metals in the vegetation may be connected with this increase in productivity. It is not possible, however, to conclude from the evidence whether the reduction of metal concentrations is in any way responsible for, or merely a side effect of, the increased growth.

Although there are minor exceptions to most of the chemical trends discussed, there is one of some importance. This is seen in Table 13, where the higher productivity grassland vegetation under the cover has a significantly higher concentration of lead. If this result is not an analytical error it would appear to eliminate lead toxicity as a major factor in reducing production on the metalliferous soils. In this context it is perhaps significant that in the overall rankings of 'effective dilutions' lead is in the fifth position.

The possibility of heavy metals interacting with phosphorus to reduce productivity in Teesdale has been suggested by Jeffrey and Piggot (1973), they also state that the available phosphorus in Teesdale soil was low, although available phosphorus was high. The data presented in Tables 3 and 4 show that the total and extractable phosphorus levels in Teesdale soils were higher than in Sunbiggin soils, this may have contributed at least in part to the higher summer growth rates of plants on this soil in pots. Different amounts of available phosphorus are extracted from the various fractions of soil phosphorus pool according to the method employed (John, 1972); Jeffrey and Piggot (1973) give neither figures for phosphorus, nor description of the method used for estimation, which makes a critical appraisal of their work difficult.

It has been demonstrated by several workers that at least one form of heavy metal toxicity is caused by interference with uptake of nutrient elements (Wallace, 1963; Lagerwerff, 1967; Ernst, 1968), which would be consistent with the findings of Jeffrey and Piggot (19973). In the light of the results presented in this thesis, it is necessary to ask how a rise in temperature might alieviate this effect.

If the mechanism of heavy metal tolerance was known then the effect of

Table 19 Summary of rankings of "effective dilutions" for all experiments (see Tables 16 and 17 for details)

	Al	Zn	Cd	Mn	Pb	Fe	P	Mg	Ca	K
'73 cold frame Ses-Mes.	1	5	4	6	3	2	7	10	9	(8)
'74 cold frame Ses-Mes. metalif	4	3	2	1	10	6	7	5	9	8
'74 cold frame Ses-Mes. non-metalif	2	4	9	7	1	3	3	5	6	10
'74 cold frame Tof. metalif	5	4	2	1	8	10	10	9	6	7
'74 cold frame Tof. non-metalif	1	2	3	7	10	6	6	9	4	8
Barley Teesdale soil	5	2	1	(4)	3	6	6	7	9	8
Barley Sunbiggin soil	3	1	2	(4)	5	8	8	7	10	9
R_j	21	21	23	30	40	41	46	52	53	58
$\left(R_j - \frac{R_j}{N}\right)^2$	306 .25	306 .25	240 .25	72 .25	2 .25	6 .25	56 .25	182 .25	210 .25	380 .25

s = 1762.50
W = 0.4360
estimated χ^2 = 27.49
Theoretical χ^2 with 9 degrees of freedom is 21.67 for p = 0.01 and 27.88 for p = 0.001
For details of method see Appendix B.
Data for the ranks in brackets had been lost therefore these have been estimated on the basis of those remaining.

temperature on non-tolerant species might also be easier to understand. Ruther (1967) stated that tolerance does not involve the non-uptake of the heavy metals; Turner et.al. (1966) suggested that tolerance results from accumulation within the cell wall; whereas Ernst and Weinert (1972) found that the metallicole, Silene cucubalus, had greater concentrations of zinc in cell vacuoles. None of these mechanisms indicate any possible way in which a temperature synergism might occur, because they do not directly invoke metabolic processes; however the work of Jones (1961) does. As a result of chromatographic studies with extracts of plants grown in alkaline soil, Jones suggested that tolerance of Aluminium and heavy metals may be achieved by chelation with organic acids in cell sap, therefore plants with an organic acid intracellular buffering system would be more tolerant than those with a phosphate buffering system. This explanation of heavy metal tolerance could accommodate the possibility of lower temperature excacerbating the reduction of growth in non-tolerant species growing on the metalliferous soils of Teesdale, by lowering the rate of the respiratory processes responsible for producing the organic acids. The possibility of lead directly interfering with root metabolism has already been suggested as a casual factor in the Teesdale situation (Jeffrey, 1969).

Comparison of the respiration rates of rare, and non rare species at Teesdale using field respirometry methods could be very rewarding; however certain facts concerning the respiration of arctic-alpine plants in general are known. Wager (1941) found that respiration rates in the leaves of arctic plants was higher than in leaves of temperate species for any given temperature; and Warren-Wilson (1966) demonstrated that arctic plants have a Q_{10} of about 3. Warren-Wilson also showed how the higher respiration rate could be an advantage in cold climates by utilising sugars which would otherwise accumulate and stop assimilation of carbon dioxide, which being a photochemical process is less affected by temperature, he also pointed out that arctic plants generally contain more sugar in their leaves than non-arctic ones. In his review, Billings (1974) notes that the higher respiration rates of arctic-alpine plants is particularly true of dark respiration. Billings states that temperatures above 25^{o}C cause abnormal metobolism in arctic-plants, which is one reason why they cannot compete with temperate ones; abnormal metabolism at high temperatures might be expected of any plant with an intrinsically high respiration rate. Alpine plants also contain higher levels of anthocyanin than non-alpine plants, and one suggested function of these pigments is protection against ultra-violet radiation (Caldwell 1972). However, there is definite evidence that increased tolerance of high zinc concentrations also occurs in plants with more anthocyanin (Ruther, 1967); Baumeister et al. 1967); alpine soils are usually skeletal, and therefore, likely to contain more metals per unit volume than non alpine soils, so that any increased metal tolerance might be of value to alpine species even in their 'normal' situation.

The observations in the above paragraph serve merely to emphasise the fact that arctic-alpine plants might be well equipped to cope with metalliferous situations; and of particular interest is the fact that the mechanism of metal tolerance proposed by Jones (1961), involving chelation by organic acids, the high respiration rates of arctic alpine plants, and the effects of increased temperature on the Teesdale vegetation are all consistent.

Zinc and lead are higher in both soils and vegetation at Teesdale, than in the same at Sunbiggin. The zinc levels at Teesdale are well above those reported by Doyle, et al. (1973) for limestones of the Selwyn Mountains in N.W. Canada ($\bar{x}$ 605 ppm total Zn in soil, and $\bar{x}$ 45 ppm in herbaceous vegetation); however, the concentrations of heavy metals at Teesdale are much lower than in some of the Central European metallicole situations (Ernst. 1966). Although zinc and lead are the metals traditionally associated with the Teesdale flora, the possibility of Aluminium being a significant factor should not be overlooked. Certain geological strata at Teesdale are known to have higher than normal concentration of Aluminium (T. Johnson Durham University, private communication), which would probably account for the presence of γ - aluminium oxide hydroxide (γ - AlOOH) being present at Teesdale and not at Sunbiggin (boehmite in Table 5), as well as for the higher concentration of Aluminium in the former soils (Tables 3 and 4). This difference is expressed in the tissues of most plants used in the comparative experiments. Another point of interest is that the average position of aluminium in the 'effective dilution' ranking, resulting from improving the climate, is first (Table 19).

There is much evidence that at least one form of Aluminium toxicity is a result of the Aluminium bringing about phosporus deficiency (Magistad 1925; Wright, 1945; Wright and Donahue 1952; Jones, 1961; Czarnowski, et al., 1971; Hoyle 1971), and Jackson (1967) points out that the symptoms of Aluminium toxicity resemble phosphorus deficiency - one of these symptoms being slower growth. These facts would be consistent with the theory of phosphorus deficiency at Teesdale suggested by Jeffrey and Piggot (1973), and even if Aluminium is not the single determining factor it may play an important contributory role.

I have discussed at length the possibility of reduced plant growth on the metalliferous soil being aggravated by the cold Teesdale climate, but the converse should not be overlooked. Howard-Williams (1972) pointed out that the general reduction in height of metallicole vegetation would increase the harshness of the microclimate: this would clearly favour plants of small stature, or with the appropriate morphological structure. Ernst (1972), working in Central Southern Africa, found a marked zonation of vegetation associated with heavy metal gradients, and that with increasing concentration in the soil there is a reduction in the size of trees, until in the zones with the highest concentration there are no trees at all. The observations of both these workers are pertinent to the Teesdale situation, where failure of the tree canopy to close at climax would have favoured the continued existence of the arctic-alpine flora.

This comparative study, involving Sunbiggin Tarn, was undertaken in the hope that light would be shed upon the Teesdale problem, therefore, that so much attention has been paid to this comparison was a necessary development of the discussion. However, it is appropriate to conclude with a few words about the comparative approach in general, and Sunbiggin Tarn in particular.

Vegetation comparisons are dependent upon floristics, therefore comparison of an area with a metallicole flora, with an area such as Sunbiggin is difficult when elements of the metallicole flora are a major point of the comparison. The *Scheuchzerio-Caricetea fuscae* and the *Festuco-Brometea* classes into which Bellamy et al. (1969) placed the Teesdale vegetation, and into which the Sunbiggin vegetation has been provisionally classified, do not contain any of the continental metallicole groups such as *Minuartion vernae* (Ernst 1965) (one specimen of *Minuartia verna* was recorded at Sunbiggin). However, they do point out that some of the Teesdale rarities, occurring in what they call unstable boundary complexes, are referable to continental metallicole associations. More recently Jones (1973) established the presence of heavy metal associations in the class *Violetalia calaminariae* (Oberdorfer, 1970) in Upper Teesdale.

Unfortunately, to add to the difficulties of comparison Dr. Jones has also reclassified the phytosociological taxa. However, the fact that not all the Teesdale rarities are metalicole species hopefully suggests that the general comparison presented here is not vitiated, in spite of the taxonomic difficulties.

Recherche phytosociology may, as yet, be unable to answer many questions associated with the Teesdale problem, but a more prosaic view of the Sunbiggin vegetation reveals one fact of some consequence: within yards of the areas utilized in this investigation, other types of vegetation contain species such as Anemone nemorosa, Oxalis acetosella, Thuidium tamariscinum. These woodland relics indicate that Sunbiggin was covered with trees until fairly recent times; palynological examination of the peat deposits might verify this, and perhaps reveal whether or not Teesdale rarities ever grew at Sunbiggin.

From the foregoing discussion it is concluded that the lack of Teesdale rarities in the extant vegetation on Sunbiggin Fell can be accounted for by the high productivity of the vegetation, and a recent tree cover; also that most of the difference in productivity between similar vegetation units in Teesdale and Sunbiggin is mainly due to climate. However, the results presented here also suggest that the very low productivity in some of the Teesdale vegetation may result from an interaction between edaphic and climatic factors.

Manipulation of the microclimate, combined with modern sensitive methods for estimating the heavy metal content and respiration rate of individual plants, could be a rewarding approach to future Teesdale investigations.

The Teesdale flora is unique, and problematical; the Teesdale combination of climate, elevation, lattitude and metalliferous soil is also unique in the British Isles. When the uniqueness of this environmental combination is fully appreciated the unique feature of the Teesdale flora will, perhaps, become less problematical.

4. CONCLUDING SUMMARY

1. A preliminary phytosociological survey indicated general similarity between certain types of the vegetation at Widdybank Fell in Upper Teesdale, and parts of Tarn Moor near Sunbiggin, which is located about 17 miles from Teesdale.

Field measurements of C. panicea, C. lepidocarpa and S. caerules suggested that the general productivity of vegetation on Tarn Moor is considerably higher than on metalliferous soil at Widdybank Fell.

3. Growth rates in the summer of C. lepidocarpa, C. panicea, E. laticolium, S. nigricans, and T. pusilla grown in pots at Durham were higher on metalliferous Teesdale soil, indicating that most of the difference in productivity of the vegetation at Teesdale and Sunbiggin is due to climate.

4. There is some evidence that growth rates of the plants in pots were not higher on the Teesdale soil in the early part of the season, also growth of barley in pots was greater on metalliferous Teesdale soil in the mild Durham climate, but not in the cold Teesdale climate. These results suggest a possible interaction whereby the nature of the Teesdale soil exacerbates reduction of growth caused by low temperatures.

5. Experiments with cold frames appear to support the proposition in (4), because slight amelioration of climate caused a greater increase in the growth of vegetation on metalliferous soils than on non-metalliferous soils.

6. Higher levels of heavy metals in the soil at Teesdale were reflected in the tissues of C. panicea collected in the field, but the higher levels of exchangeable 'nutrients' and phosphorus in the Teesdale soil were not; these latter were, for the most part, significantly higher in plants from Sunbiggin.

7. Concentrations of both 'nutrients' and heavy metals were greater in plants on Teesdale soil when grown in the milder climate of Durham.

8. Results show that the uptake of 'nutrients' into leaves of barley grown in pots on Teesdale soil in Durham more or less matched the increase in growth; uptake of heavy metals and aluminium did not.

9. When a completely closed cold frame gave rise to a considerable increase in the growth of vegetation on metalliferous soil at Teesdale, it was found that the concentration of nutrients in vegetation beneath the frame was the same, or slightly higher than in the low productivity vegetation outside the frame; in contrast the concentration of aluminium and heavy metals was was significantly lower in the high productivity vegetation.

10. In all, eight sets of comparative experiments were carried out in which growth of vegetation in a cold climate was compared with growth in a milder one. The effect of this improved growth on the concentrations of various elements has been assessed by a ranking procedure. Results of this test show that the 'effective dilution' of aluminium in the above ground tissue is greatest, and that of potassium the least; also that the 'effective dilation' of heavy metals in general is greater than 'nutrients'.

11. It is pointed out that certain known facts regarding the respiration of arctic-alpine plants, the mechanism of heavy metal tolerance proposed by Jones (1961), and the results presented in this thesis, are all quite consistent.

12. It is concluded that the lack of Teesdale rarities on Tarn Moor may be due to the high productivity, and a recent tree cover which is indicated by the presence of woodland relect species in the adjacent communities.

13. It is further concluded that the conbined presence of arctic-alpine flora of Teesdale is due to a combination of metalliferous soil and adverse climate, which also probably helped to prevent the complete closure of the tree canopy during the period when the fells of Upper Teesdale were wooded.

5. ACKNOWLEDGEMENTS

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LIST OF FIGURES

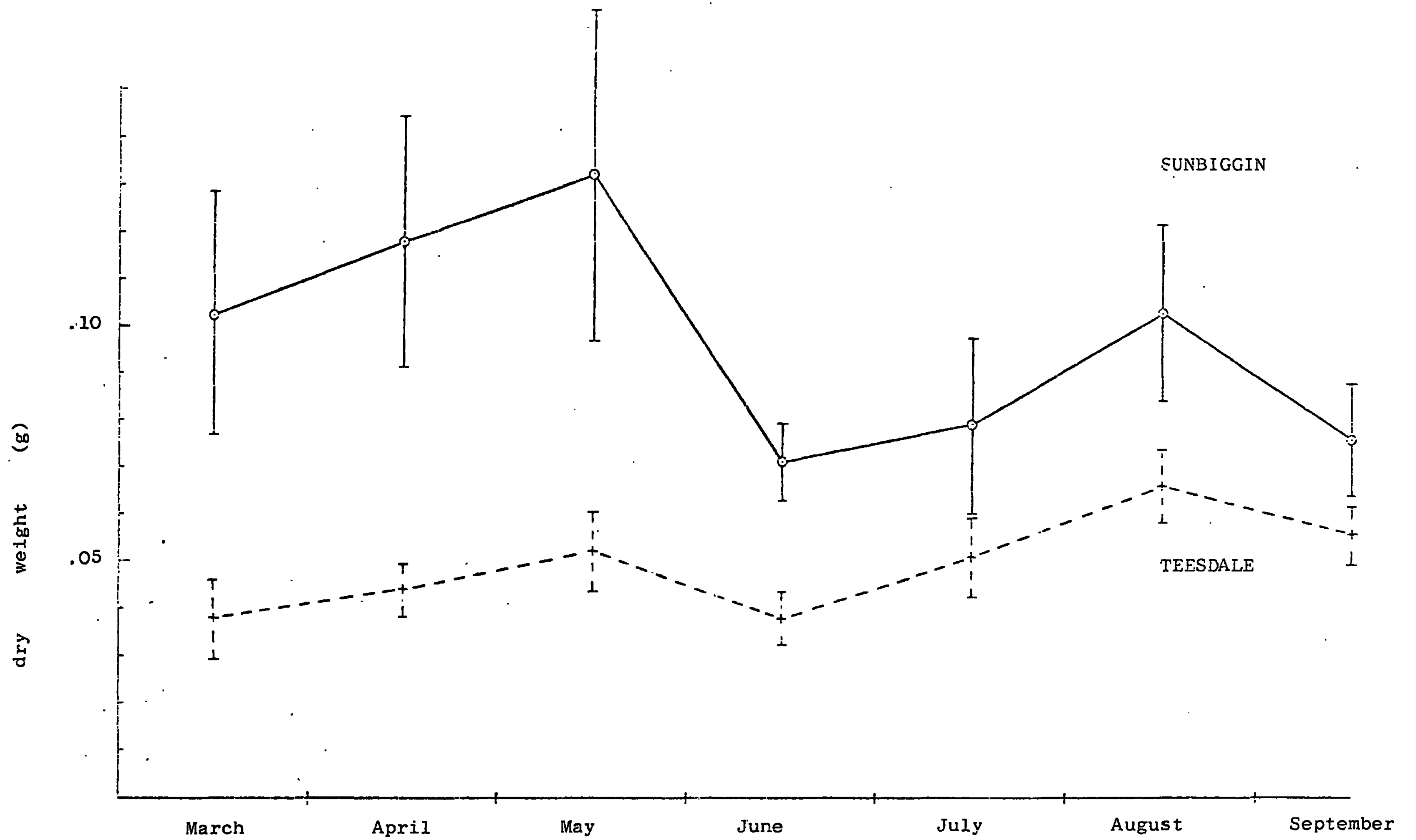


Fig. 1 Average weights of individual plants of Carex panicea throughout growing season on Tofieldietalia

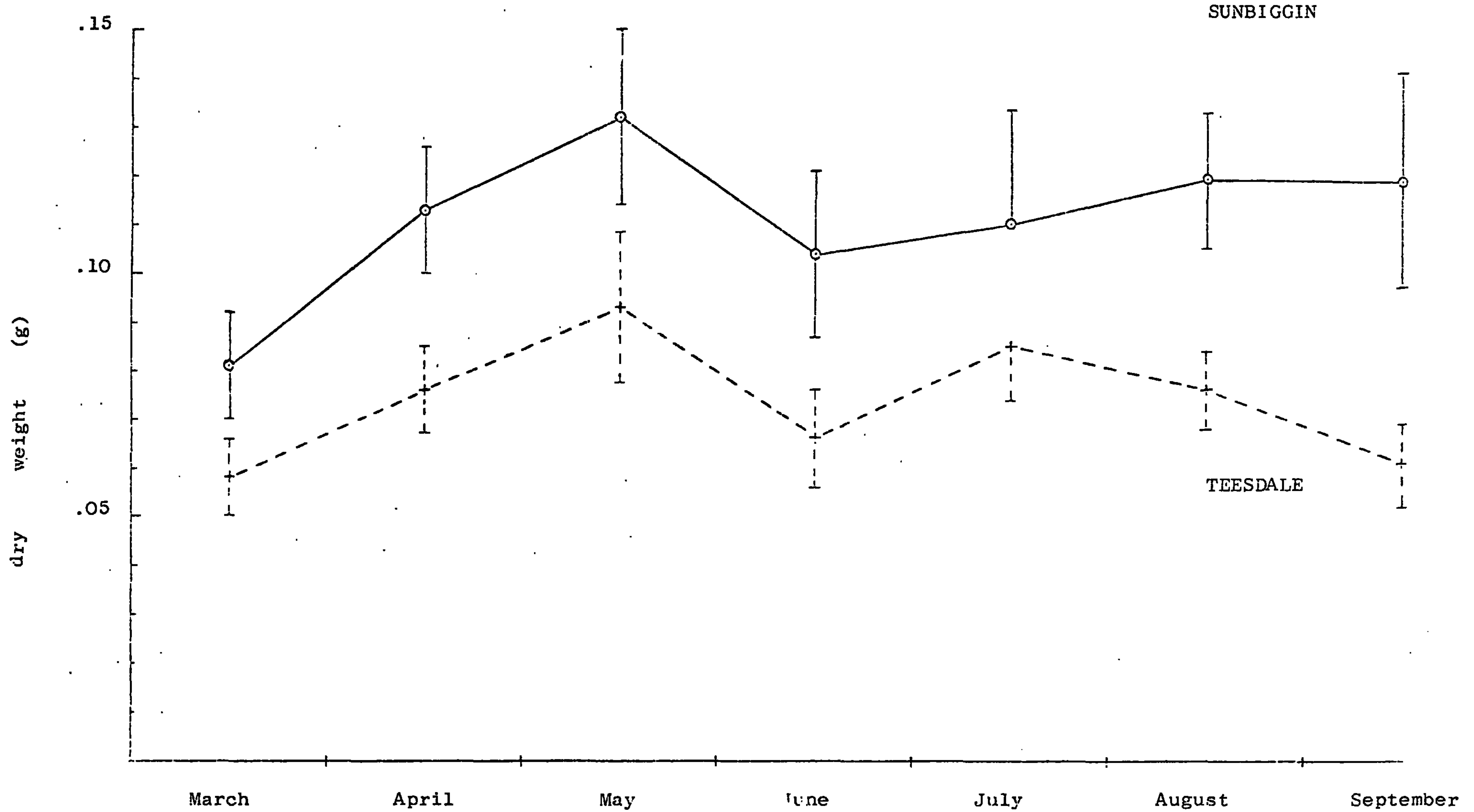


Fig. 2 Average weights of individual plants of Carex lepidocarpa throughout growing season on Tofieldietalia

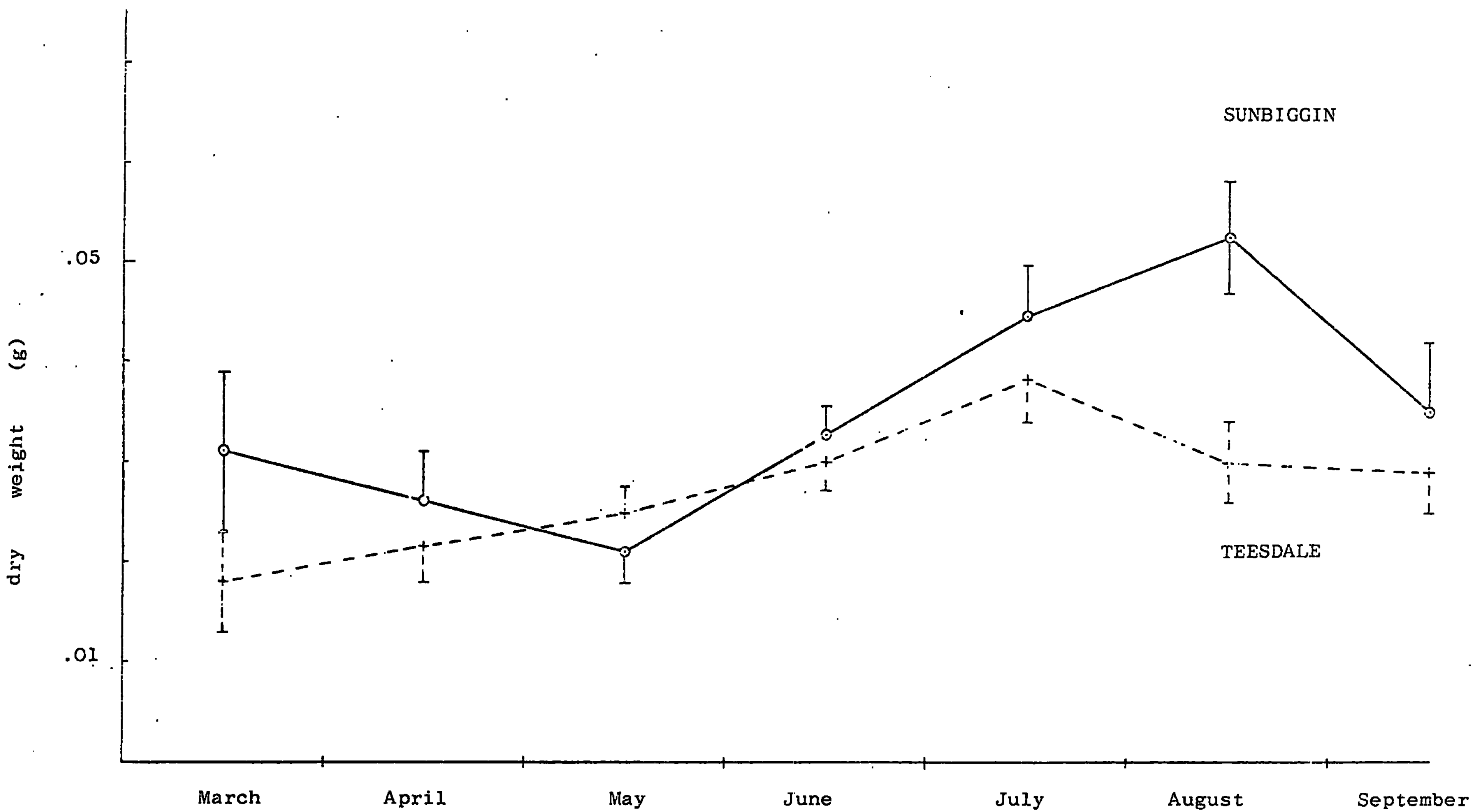


Fig. 3 Average weights of individual plants of Sesleria caerulea throughout growing season on Tofieldietalia

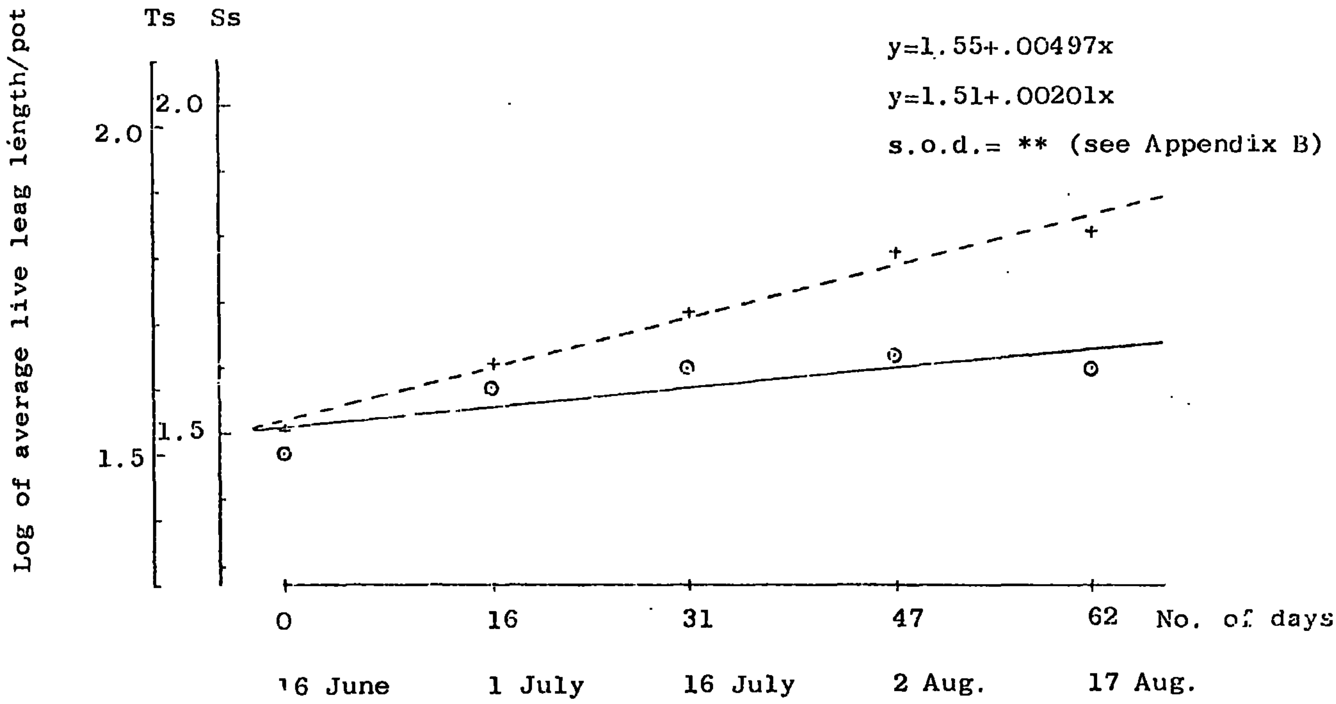


Fig. 5 Growth of Carex panicea in pots at Durham

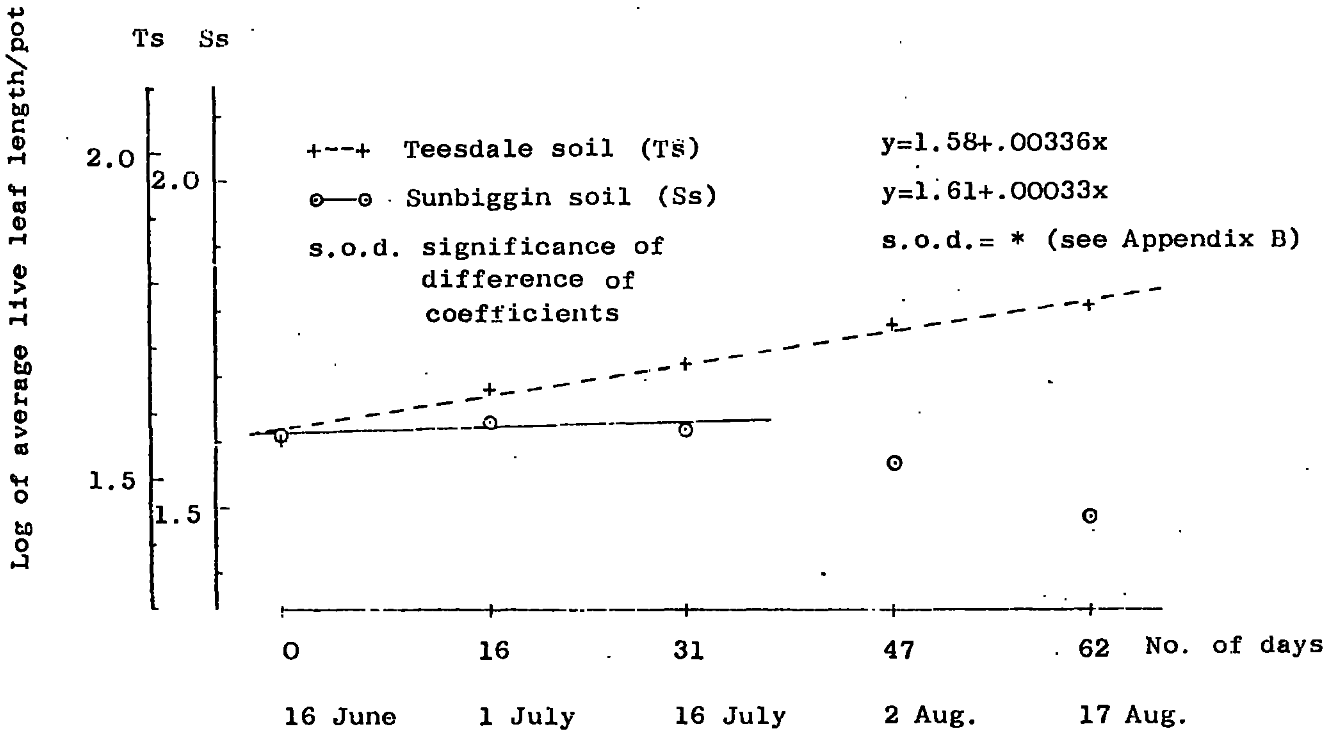


Fig. 4 Growth of Carex lepidocarpa in pots at Durham

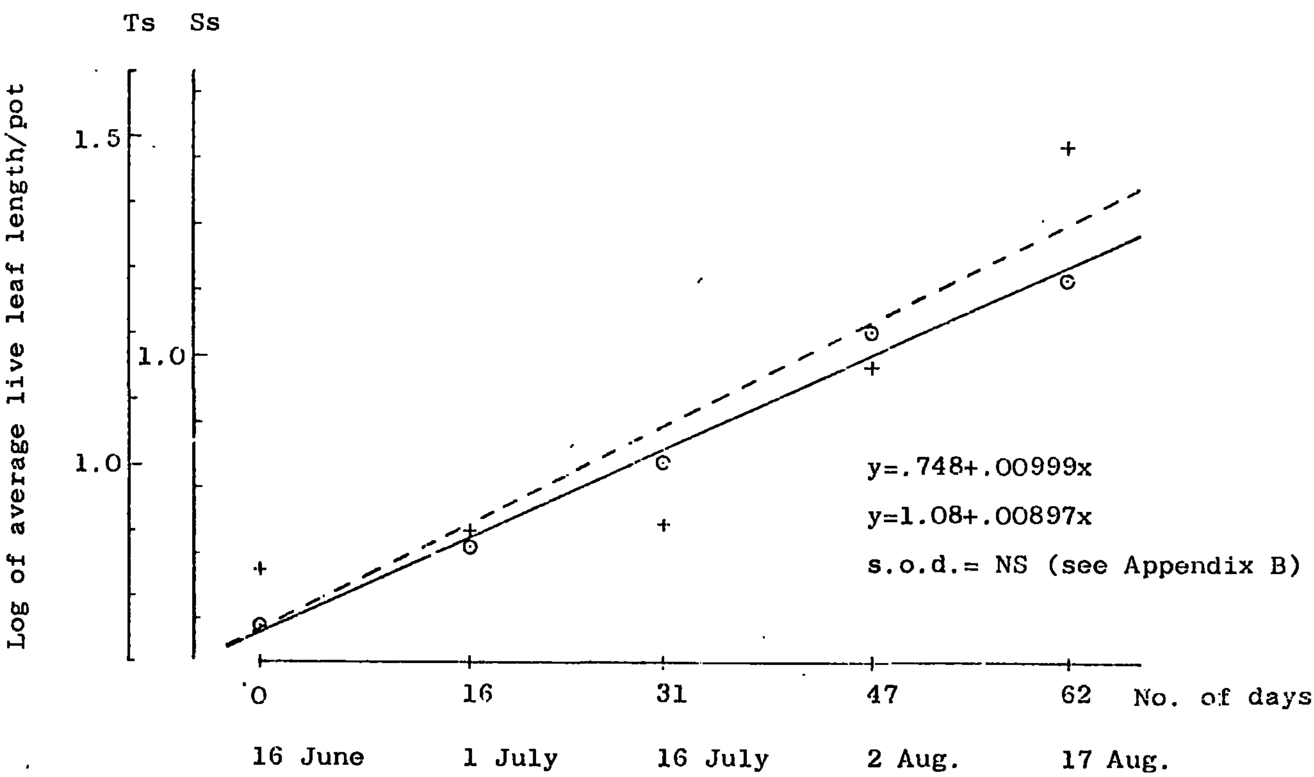


Fig. 7 Growth of <u>Schoenus nigricans</u> in pots at Durham

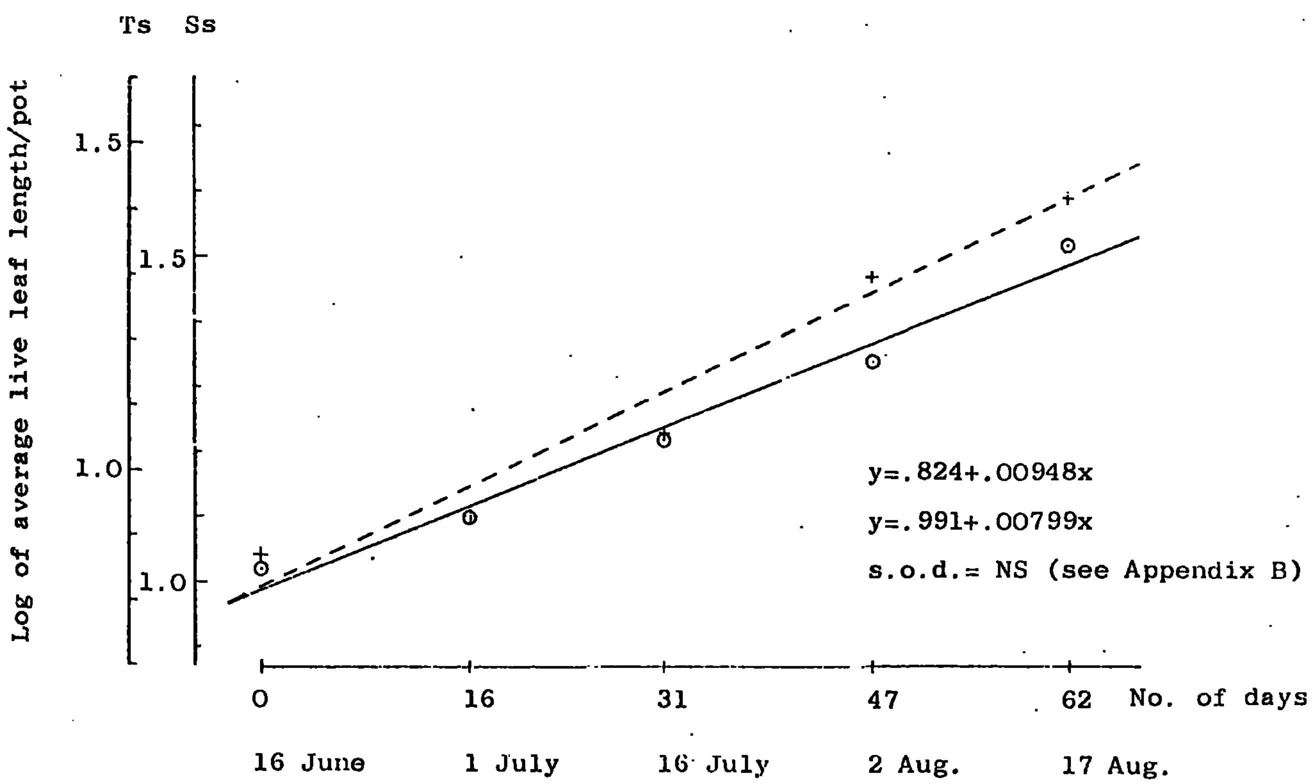


Fig. 6 Growth of <u>Eriophorum latifolium</u> in pots at Durham

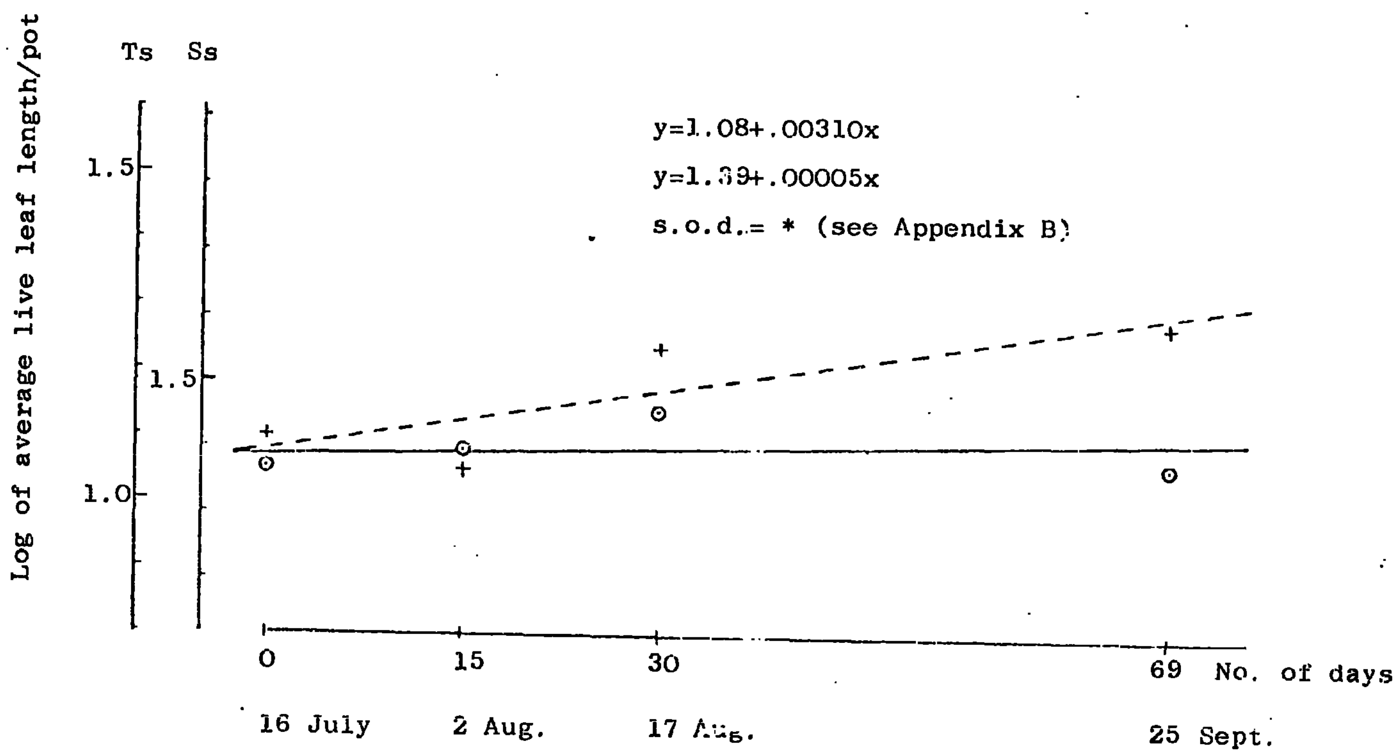


Fig. 8 Growth of Tofieldia pusilla in pots at Durham

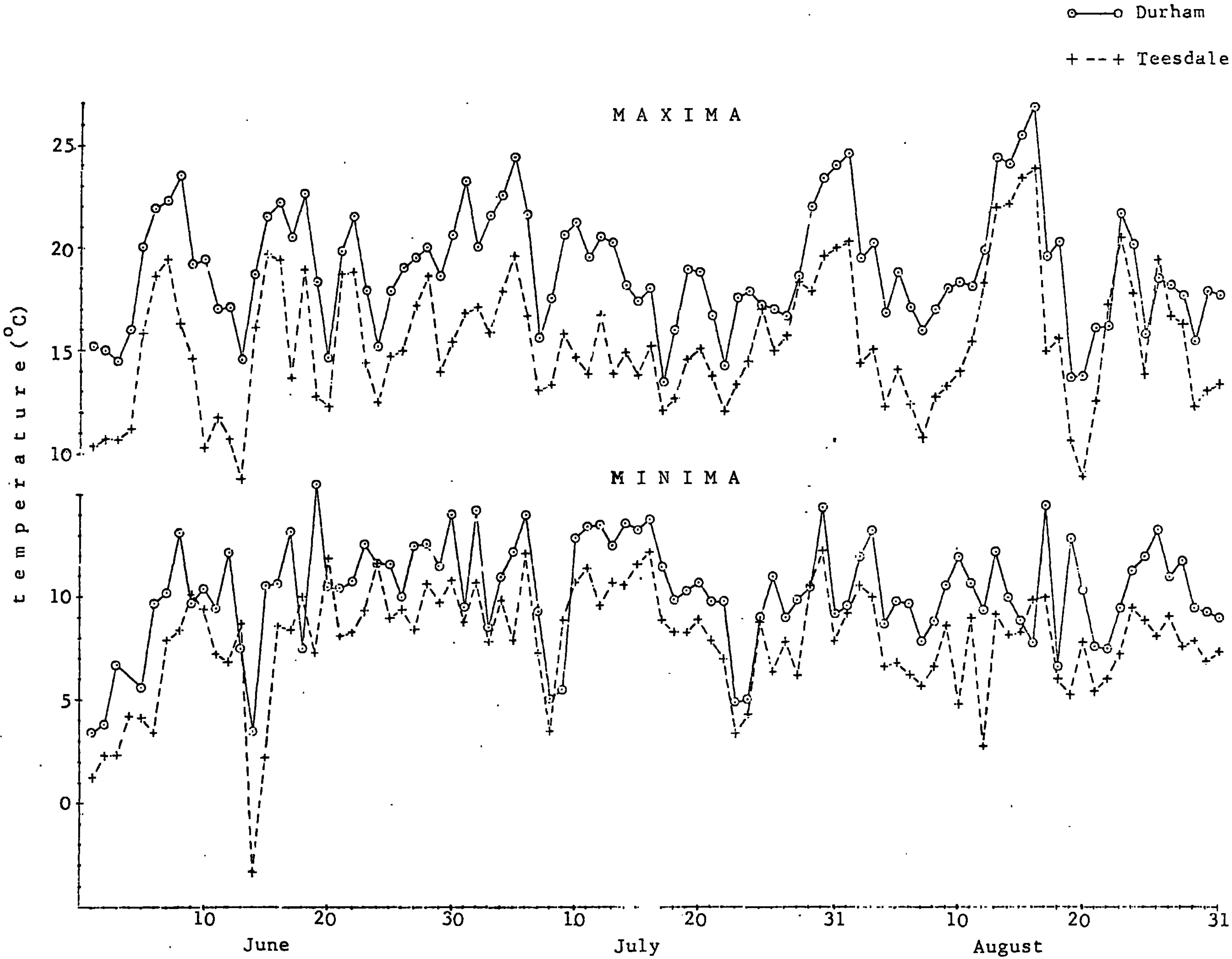


Fig. 9 Daily temperature record from Durham and Teesdale during the Barley pot experiment.

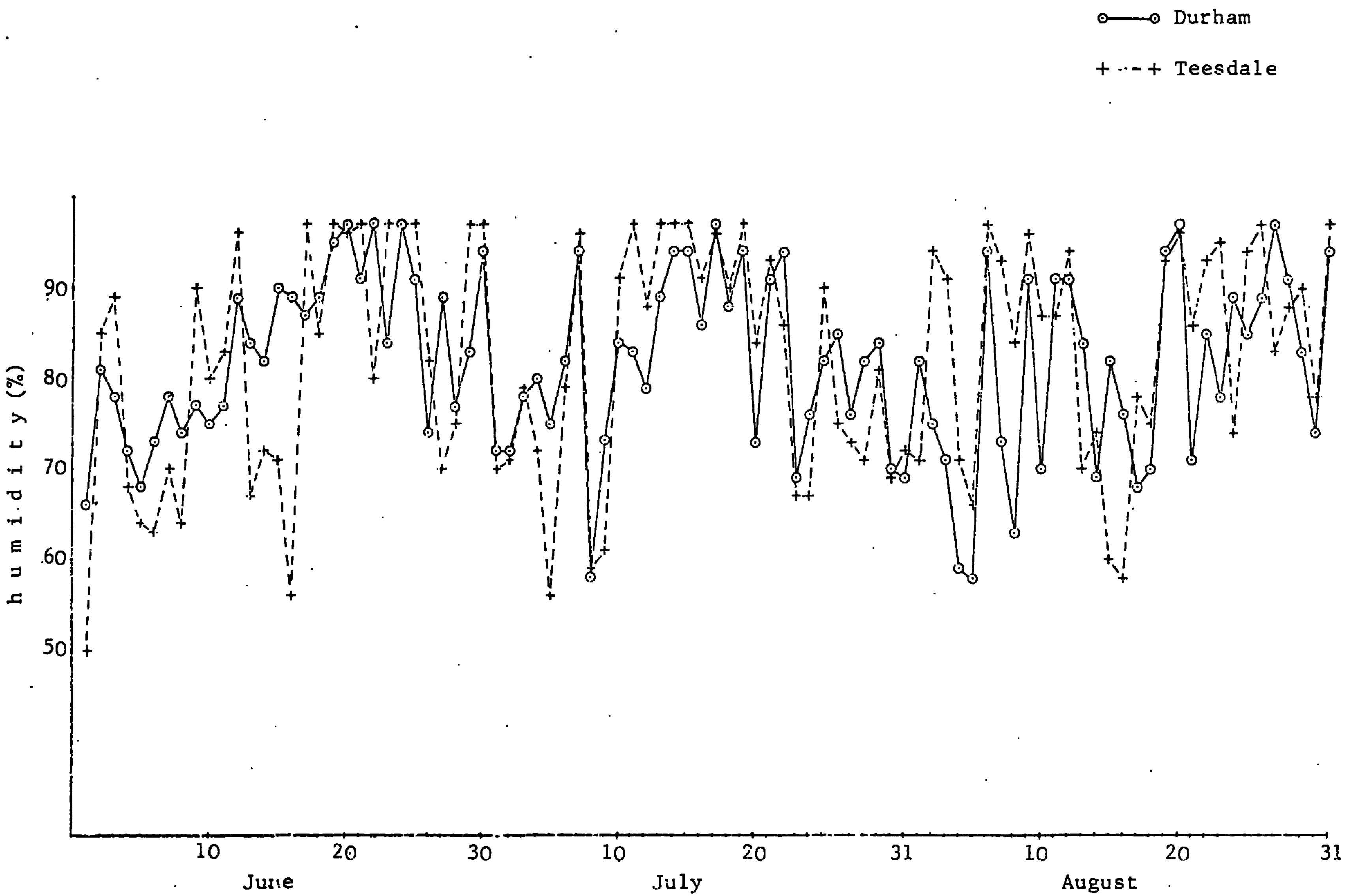


Fig.10 Daily humidity record from Durham and Teesdale during the Barley pot experiment.

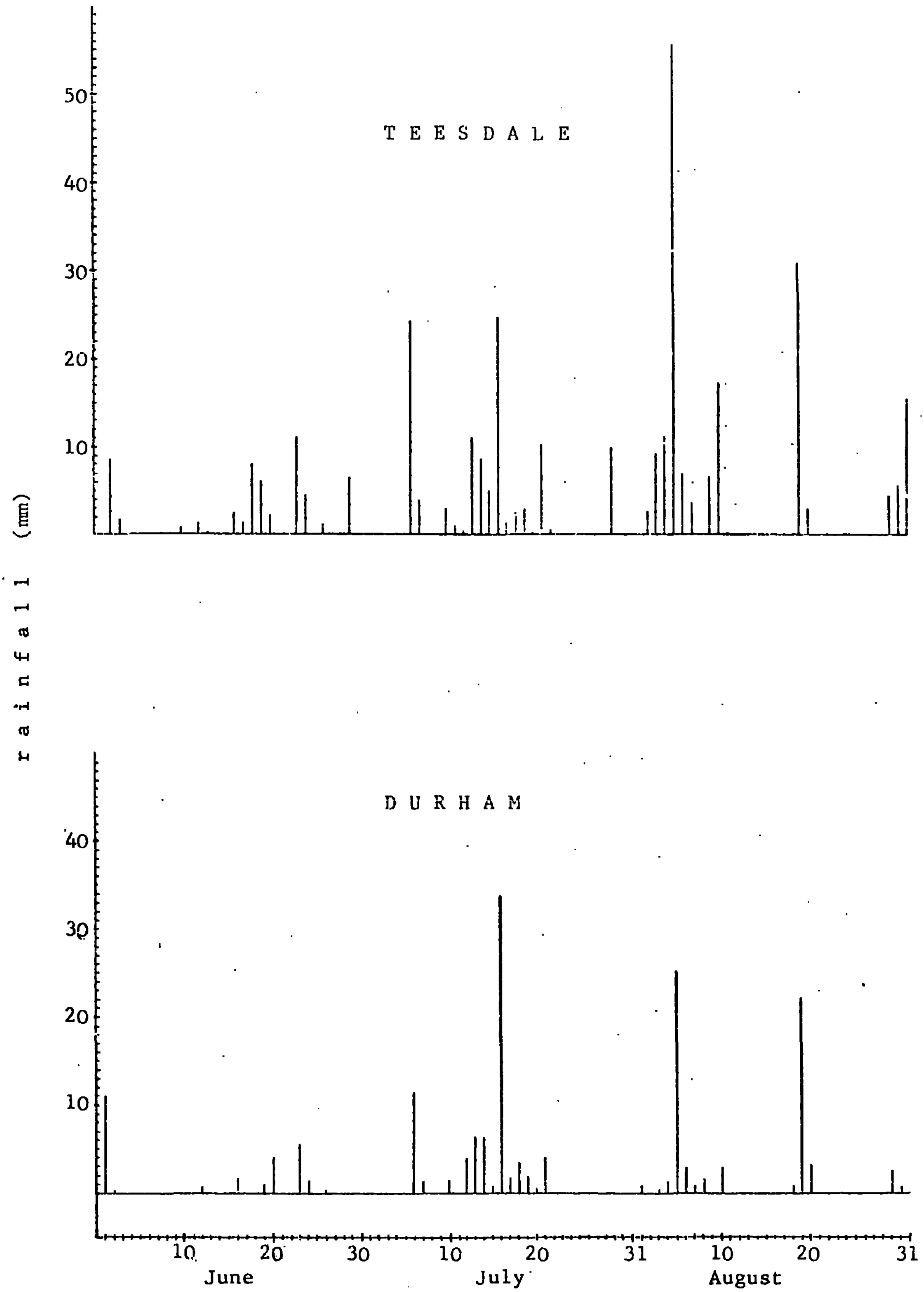
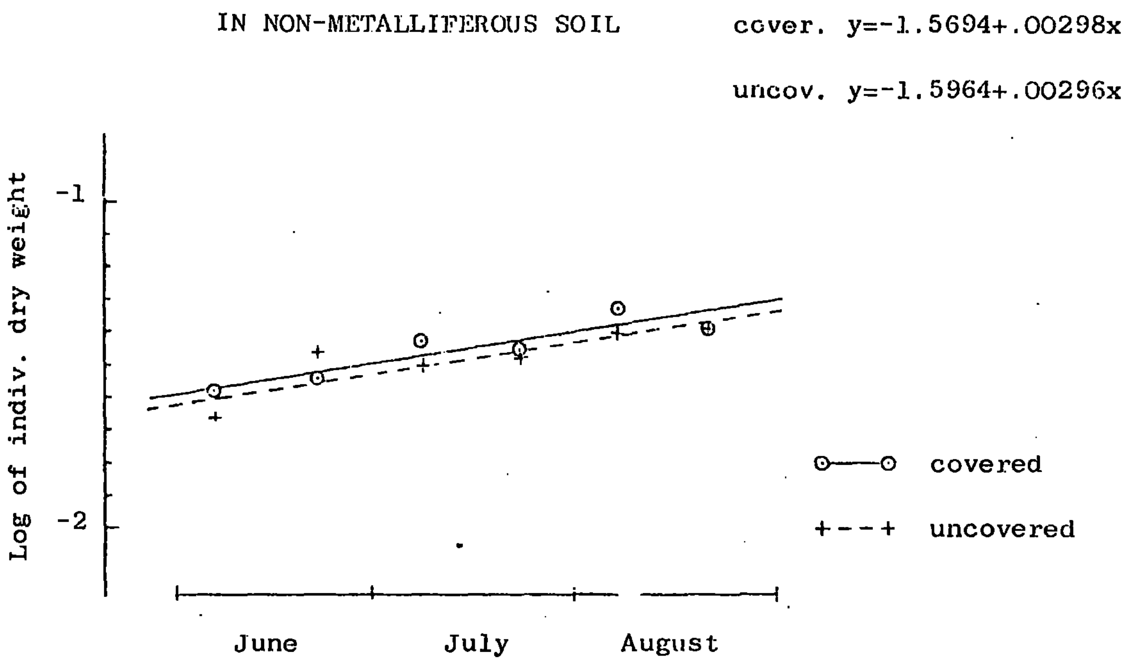


Fig.11 Daily rainfall record from Durham and Teesdale during the Barley pot experiment.



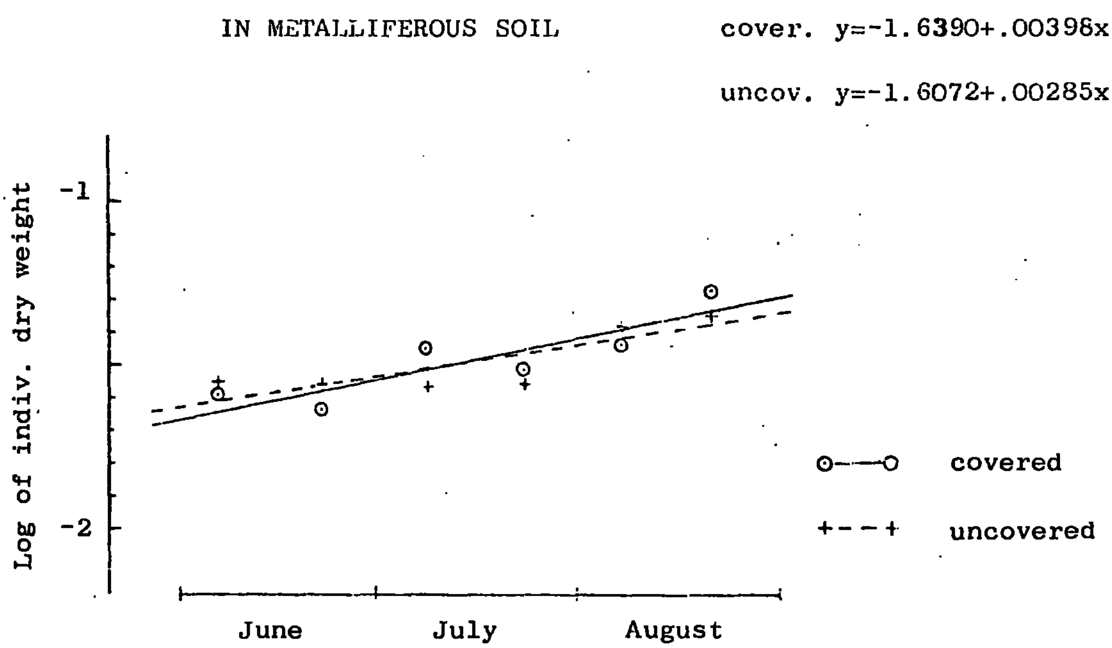
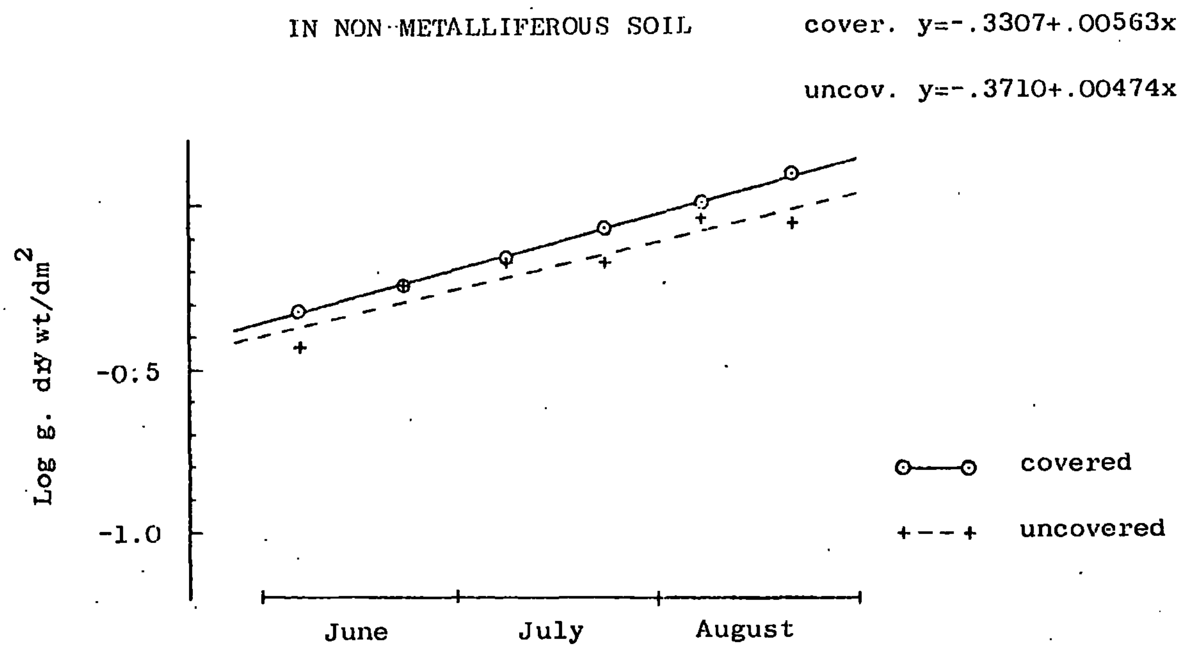


Fig.12 Log of average weights of individual plants of <u>C. panicea</u> throughout growing season on <u>Tofieldietalia</u>



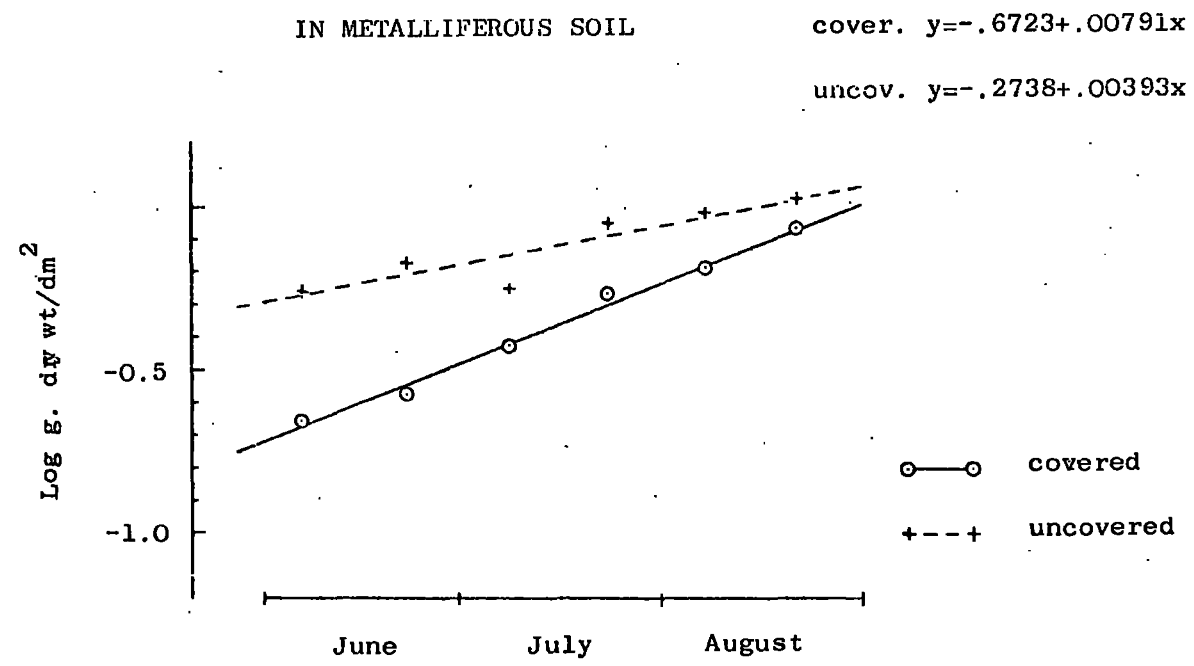
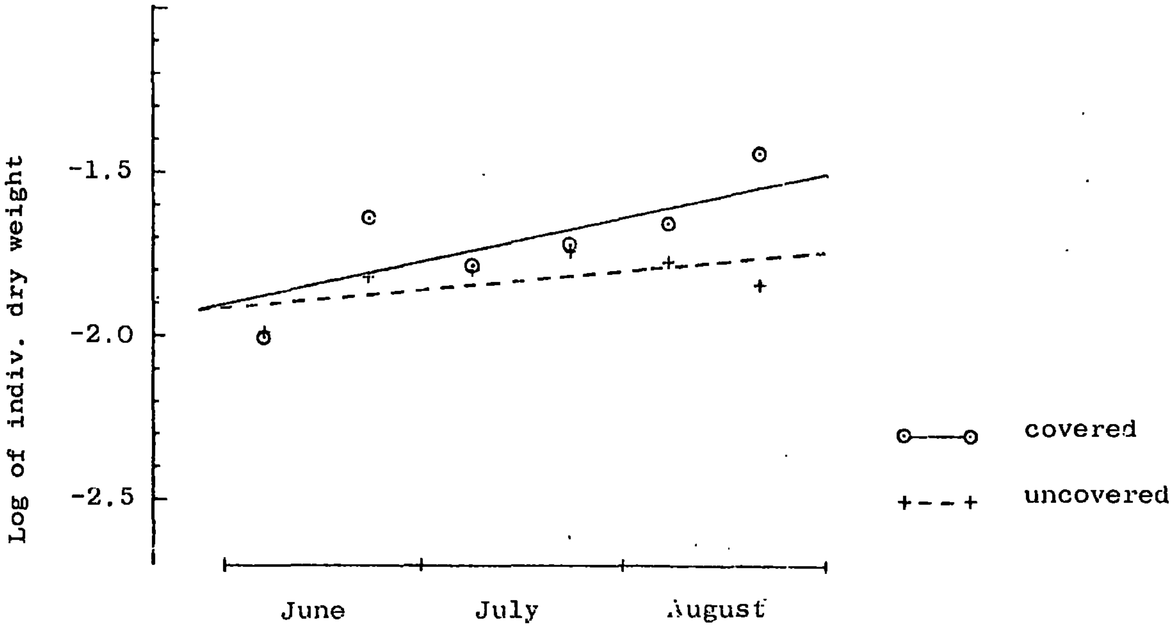


Fig. 13 Log of standing crops of all remainder sp. growing on *Tofieldietalia*

IN NON-METALLIFEROUS SOIL

cover. y=-1.9163+.00539x

uncov. y=-1.9001+.00186x



IN METALLIFEROUS SOIL

cover. y=-1.9789+.00344x

uncov. y=-2.2276+.00223x

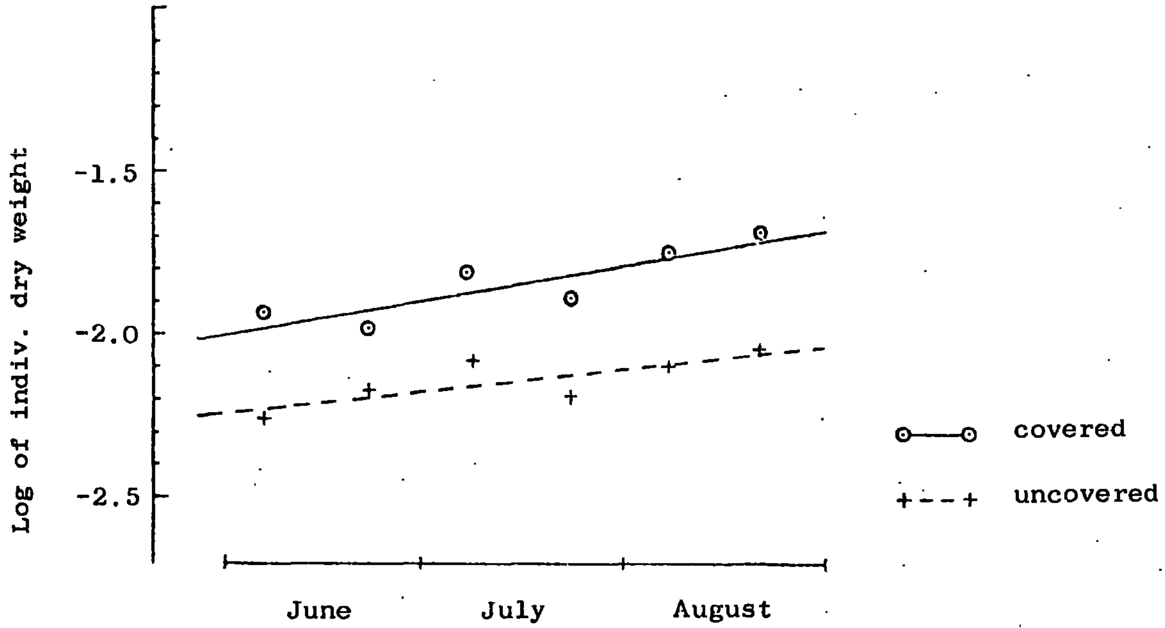


Fig. 14 Log of average weights of individual plants of Sesleria caerulea throughout growing season on Seslerio-Mesobromion

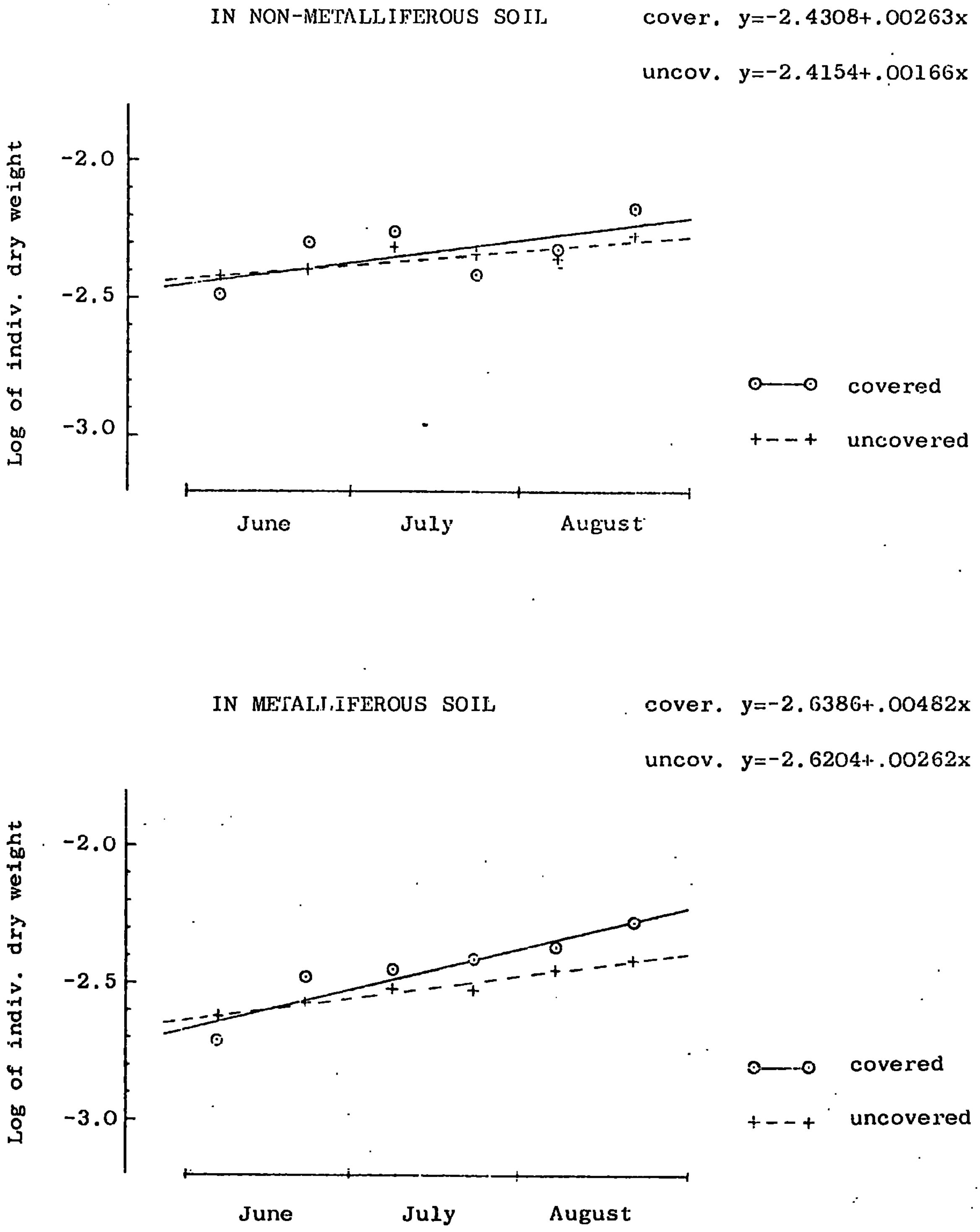
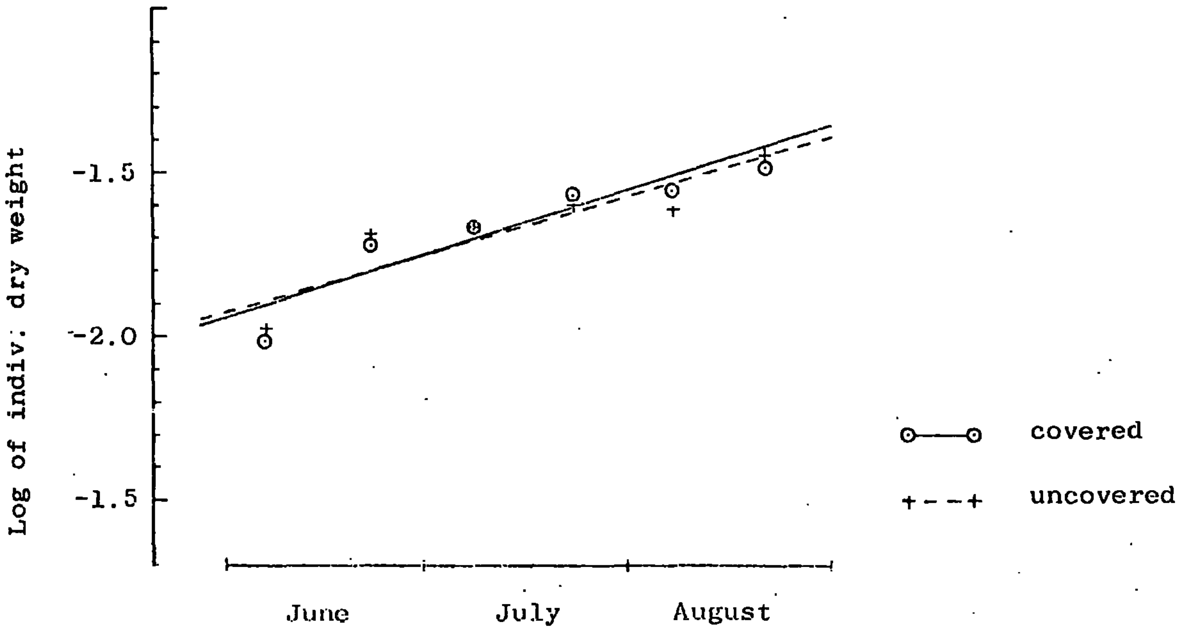


Fig. 15 Log of average weights of individual plants of F. ovina throughout growing season on Seslerio-Mesobromion

IN NON-METALLIFEROUS SOIL cover. y=-1.9087+.00621x

uncov. y=-1.8902+.00567x



IN METALLIFEROUS SOIL cover. y=-1.7899+.00423x

uncov. y=-1.8774+.00142x

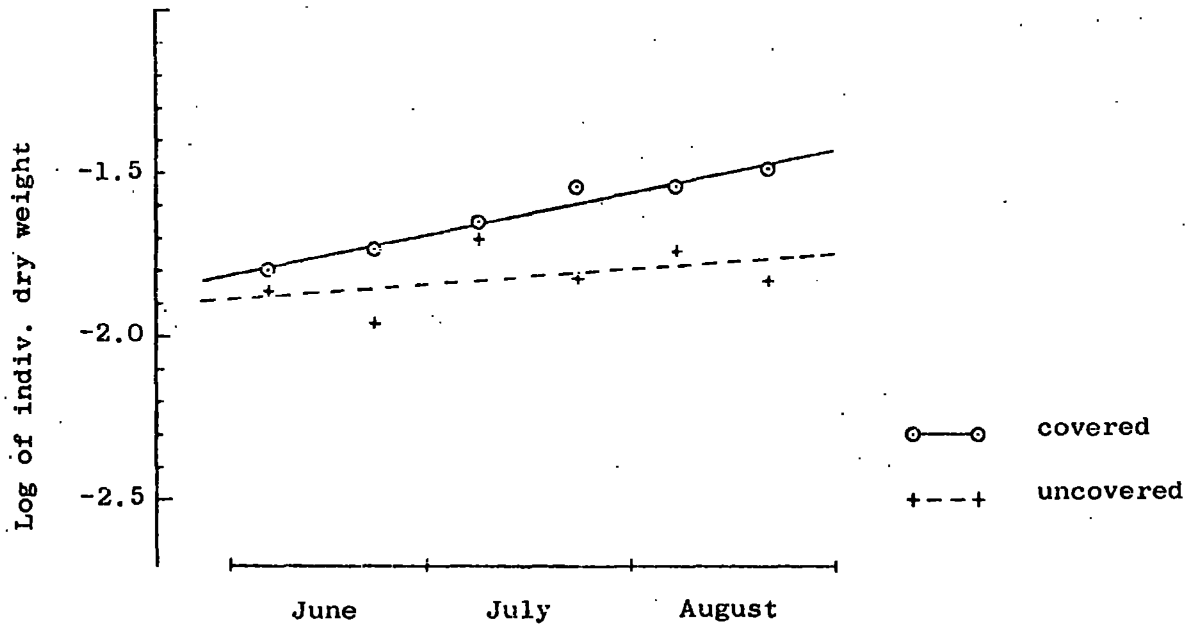
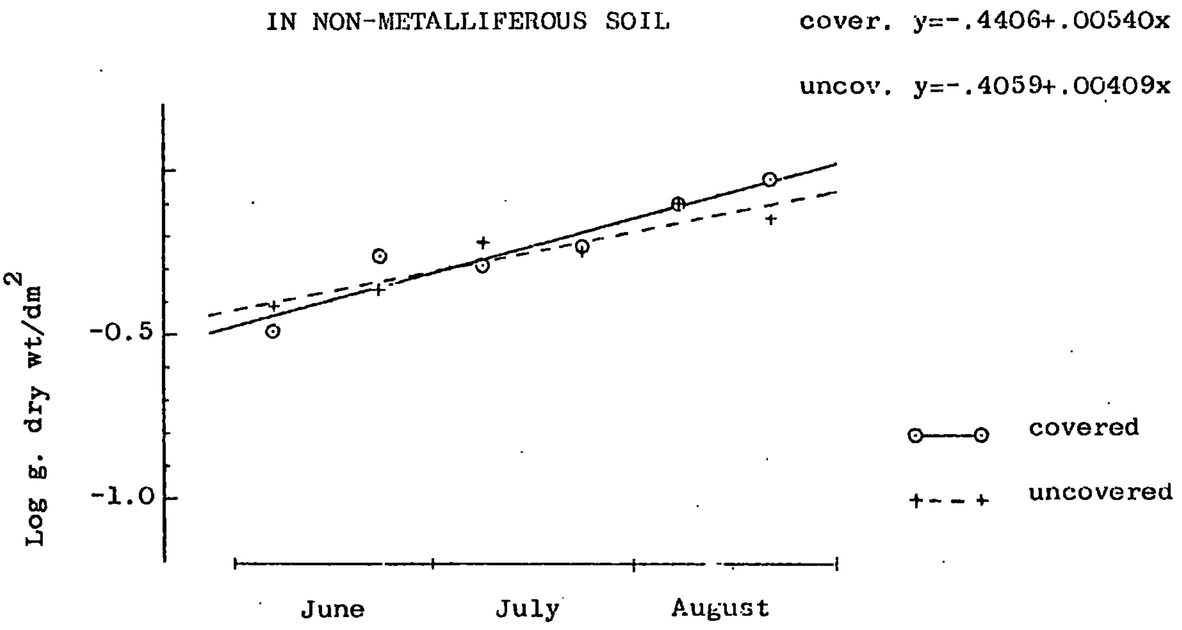


Fig.16 Log of average weights of individual plants of C. panicea throughout growing season on Sesleric-Mesobromion.



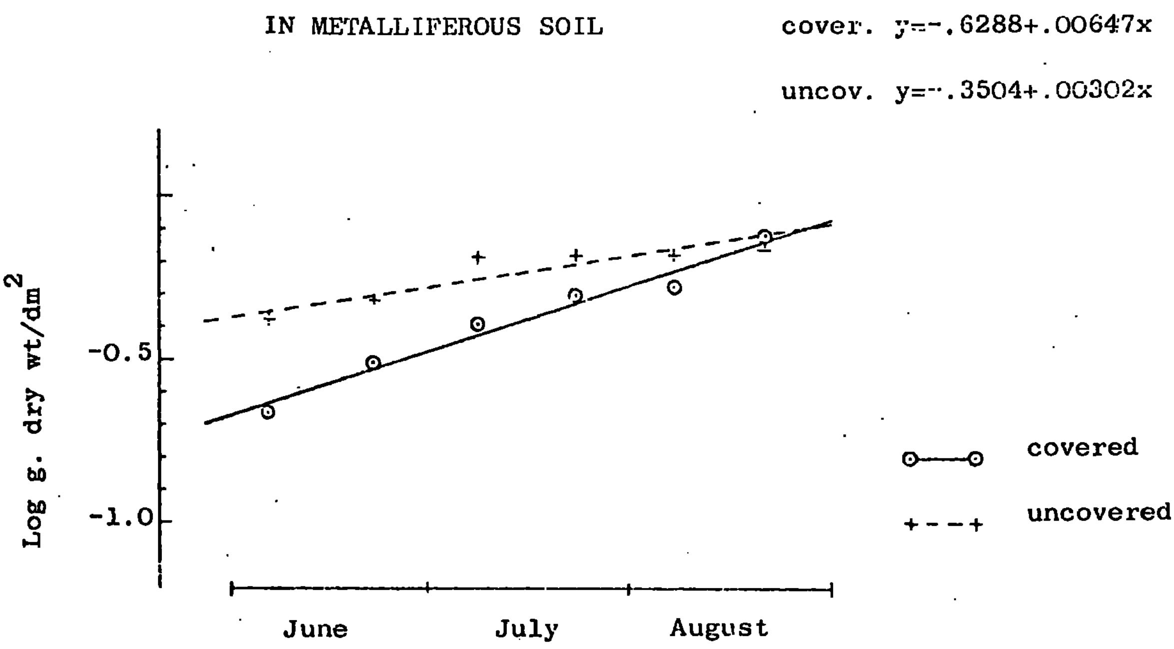


Fig.17 Log of standing crops of all remainder sp. growing on Seslerio-Mesobromion.

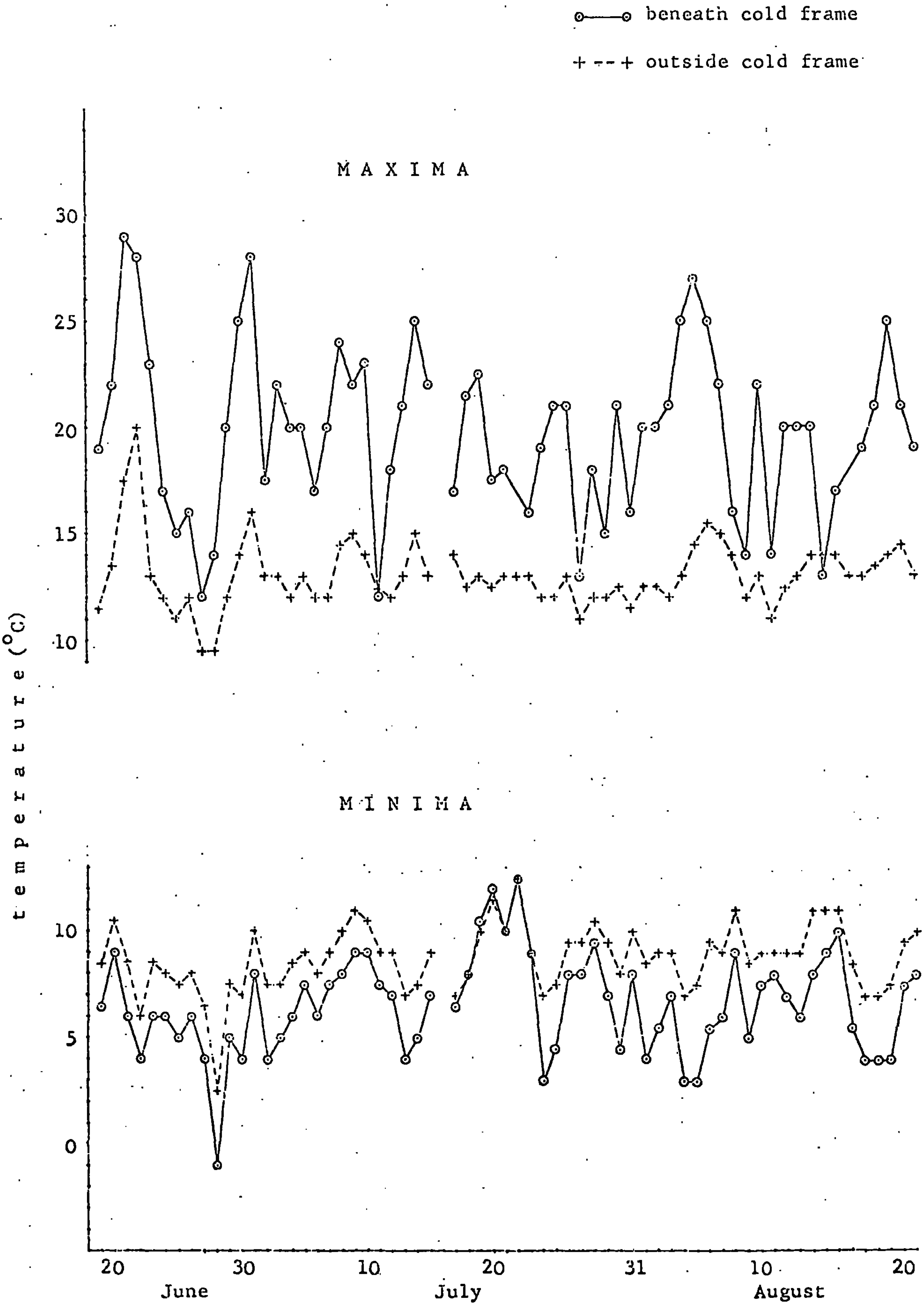


Fig.18 Daily temperature record from the metalliferous Keslerio-Mesobromion site.

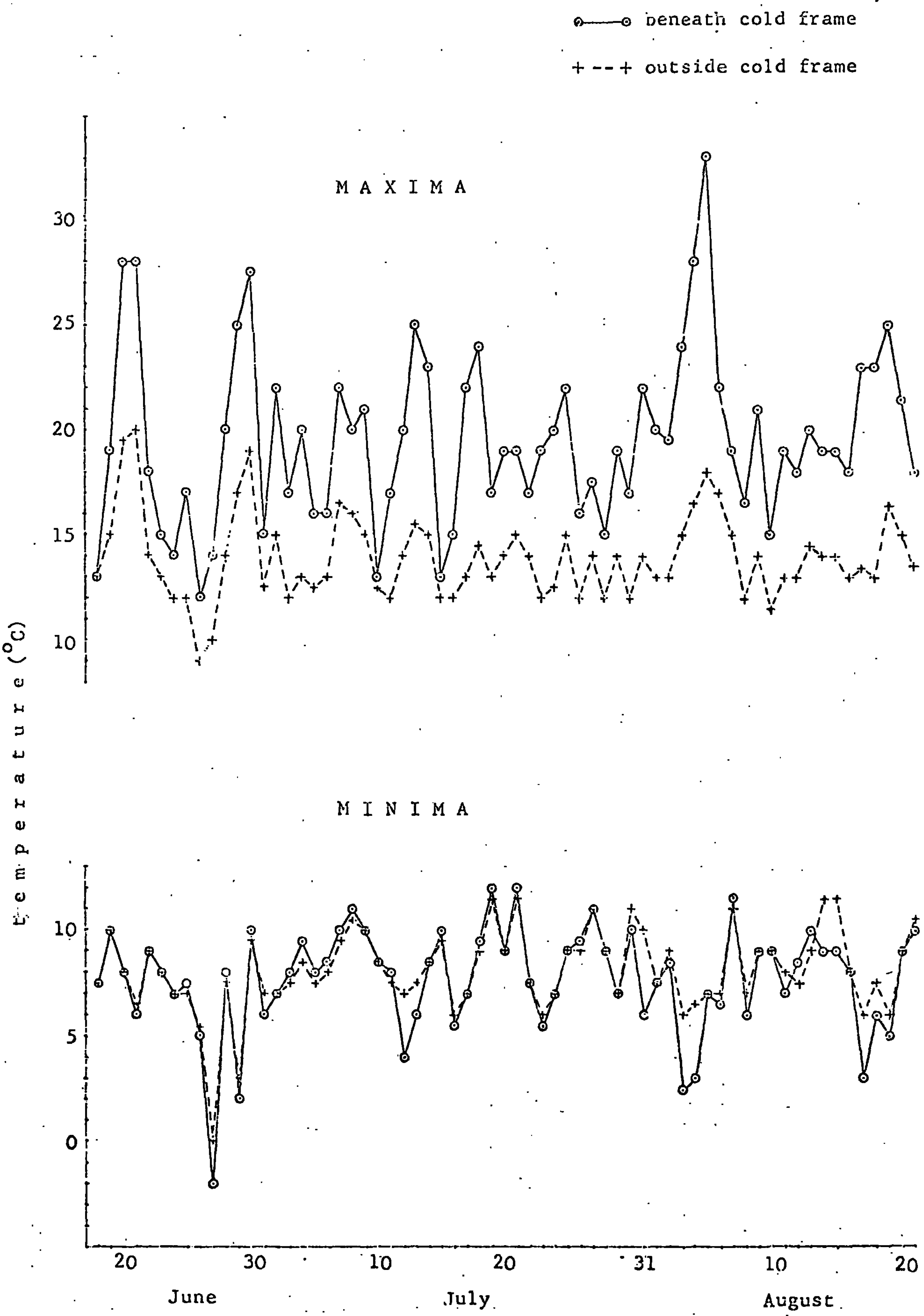


Fig.19 Daily temperature record from the non-metalliferous Tofieldietalia site.

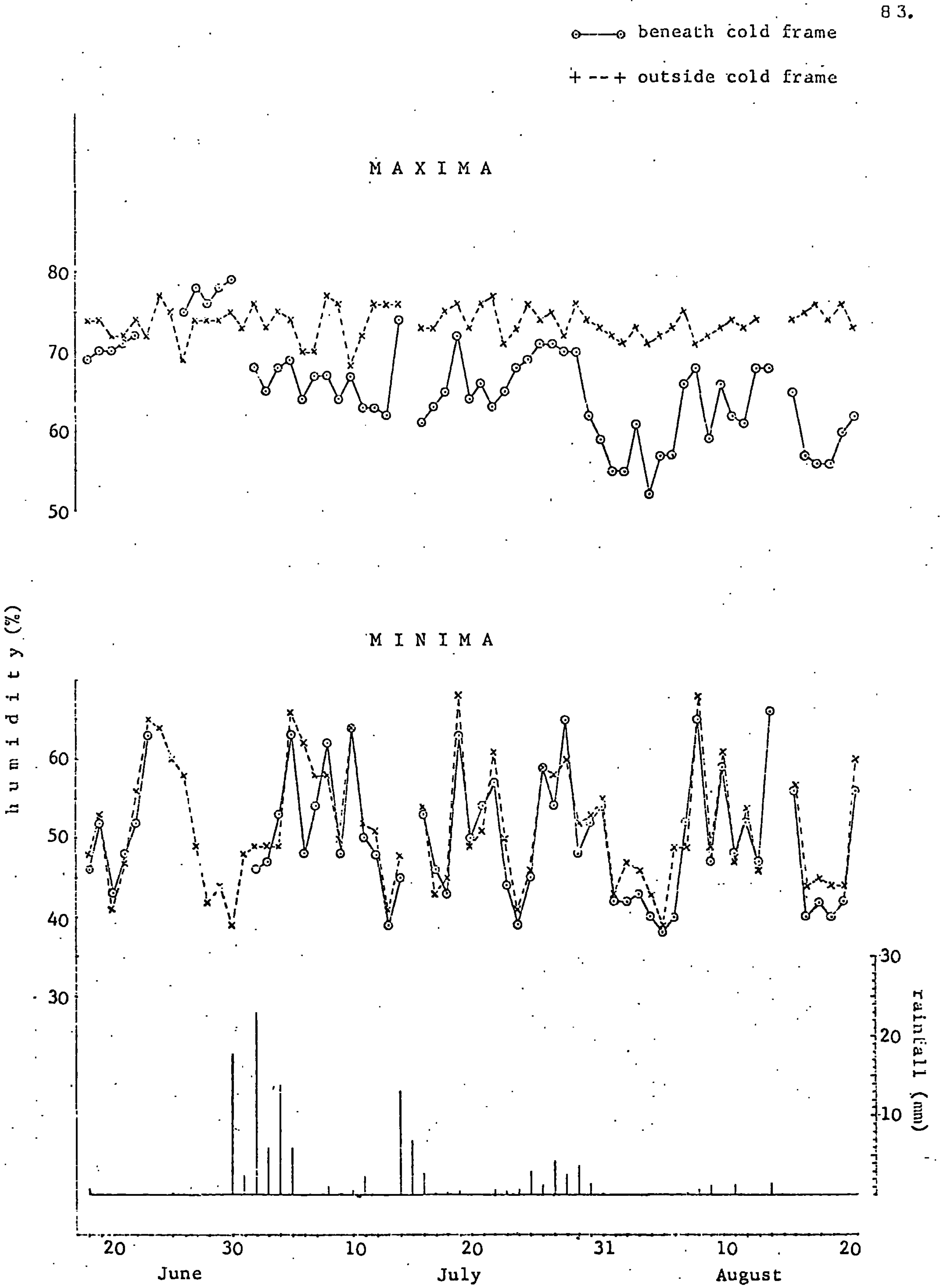


Fig.20 Daily humidity and rainfall record from the metalliferous Seslerio-Mesobromion site.

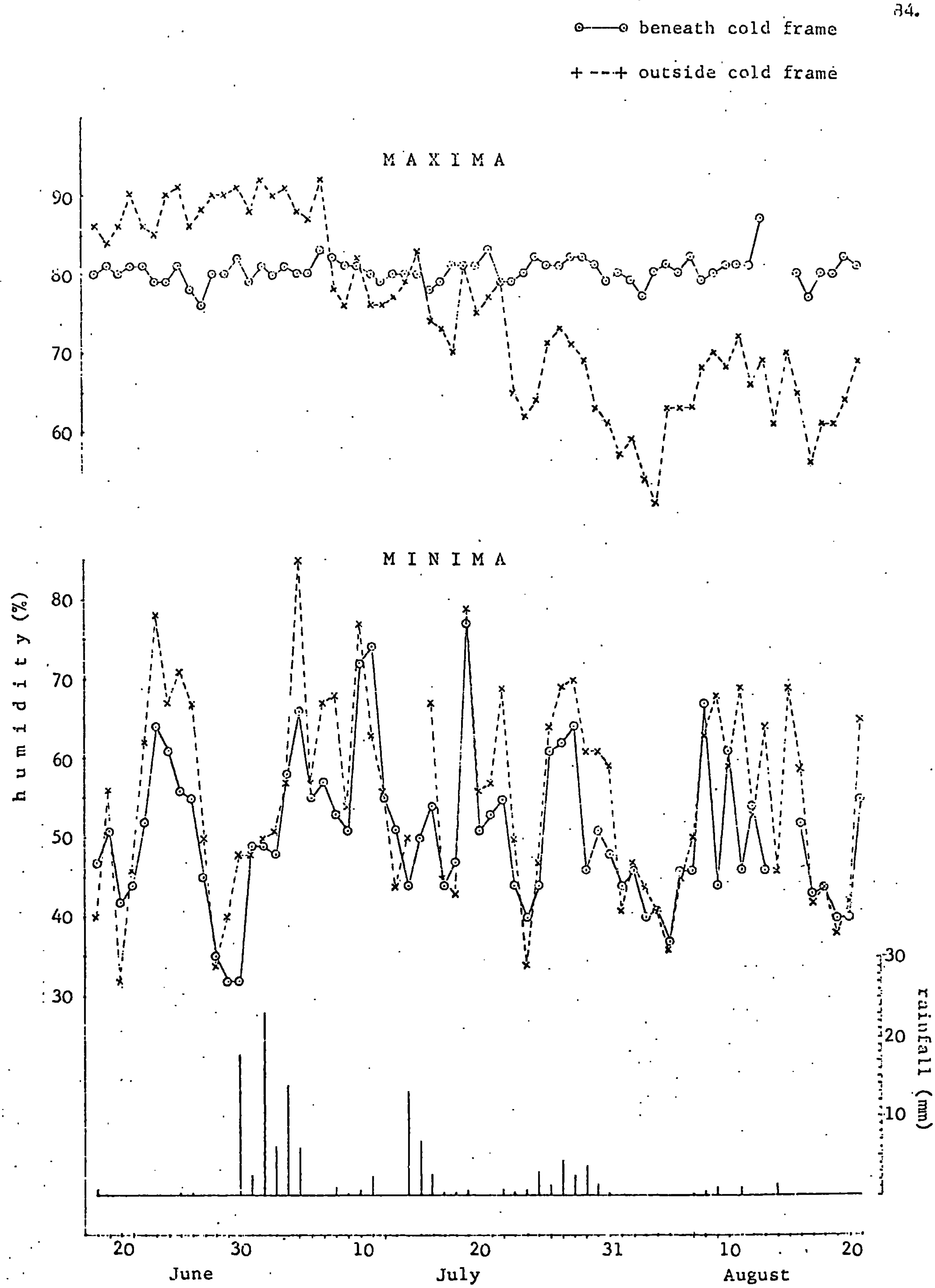


Fig.21 Daily humidity and rainfall record from the non-metalliferous Tofieldietalia site.

LIST OF PLATES

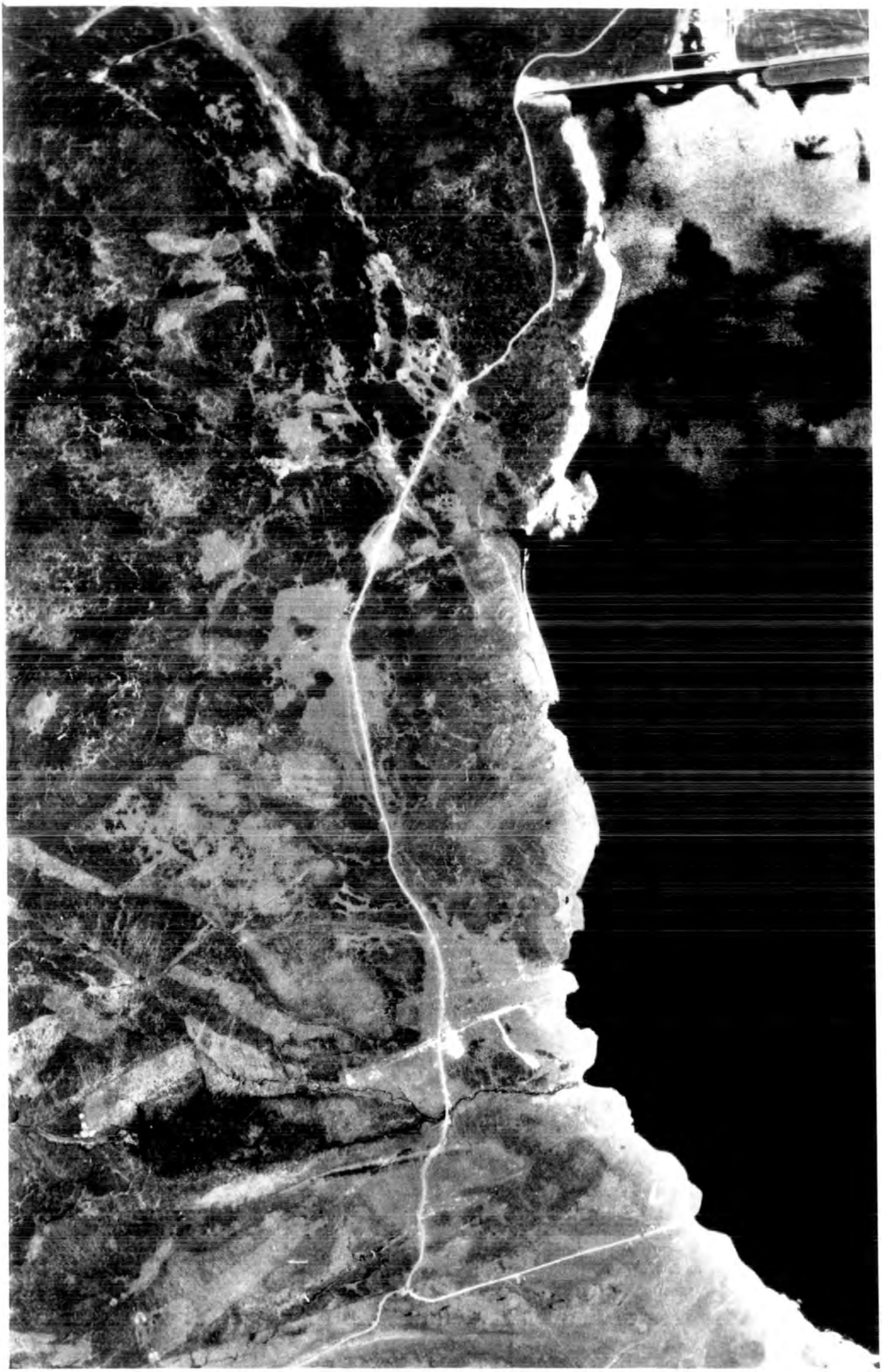


PLATE 1 EXPERIMENTAL AREA ON WIDDYBANK FELL

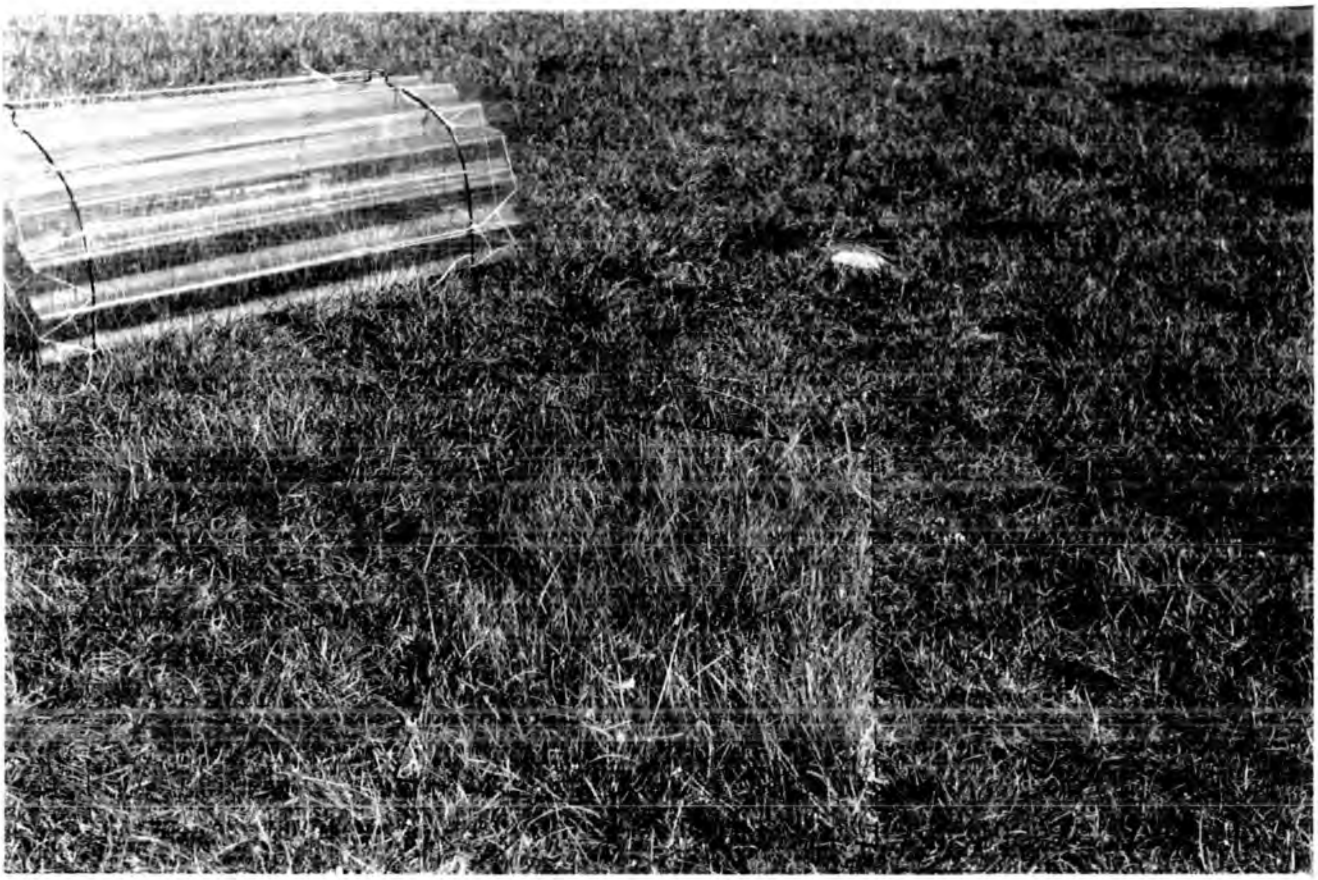


PLATE 2 END OF THE 1973 COLD FRAME EXPERIMENT

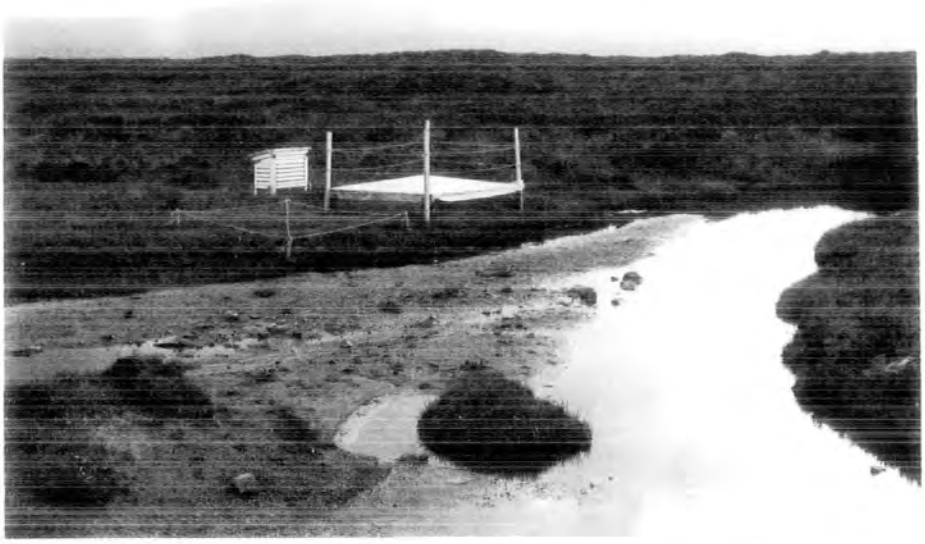


PLATE 3A 1974 'FLUSH' SITE NON-METALLIFEROUS

PLATE 3B 1974 'FLUSH' SITE METALLIFEROUS

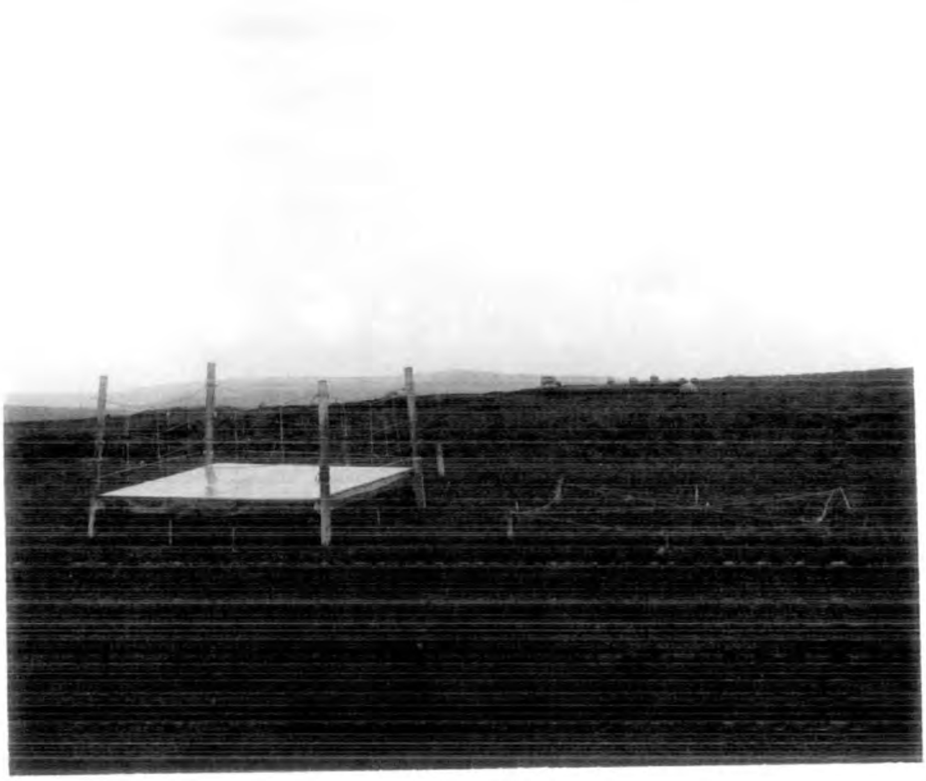


PLATE 4A   1974 GRASSLAND SITE NON-METALLIFEROUS

PLATE 4B   1974 GRASSLAND SITE METALLIFEROUS

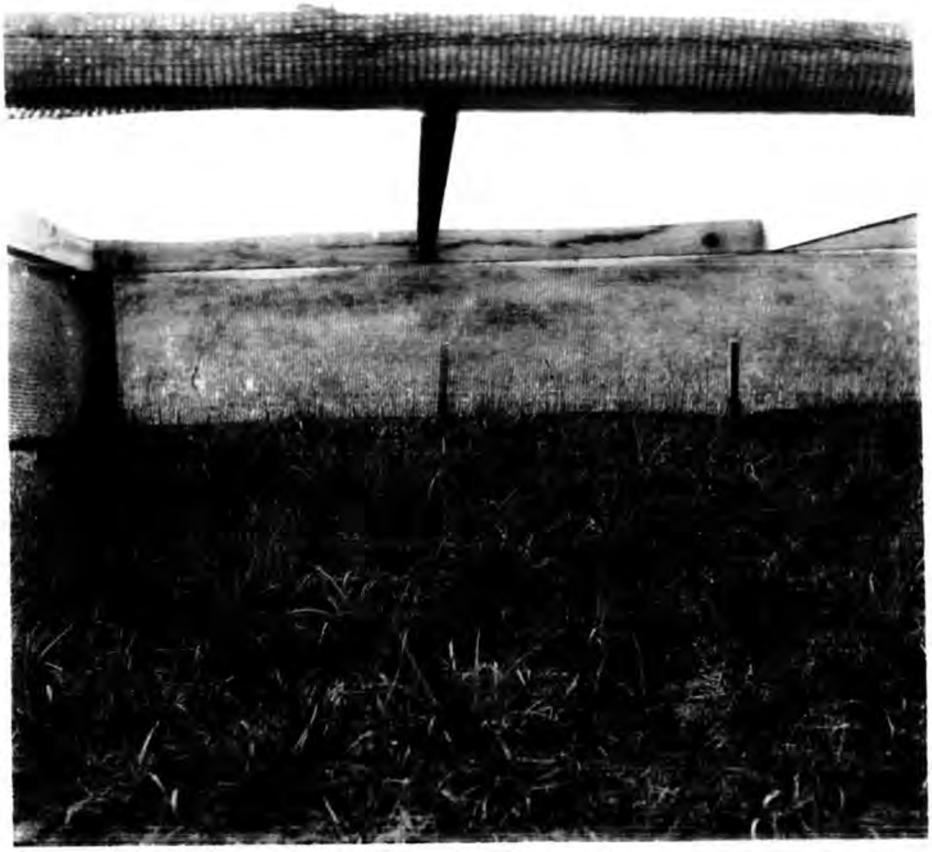


PLATE 5A METALLIFEROUS 'FLUSH' BENEATH COLD FRAME

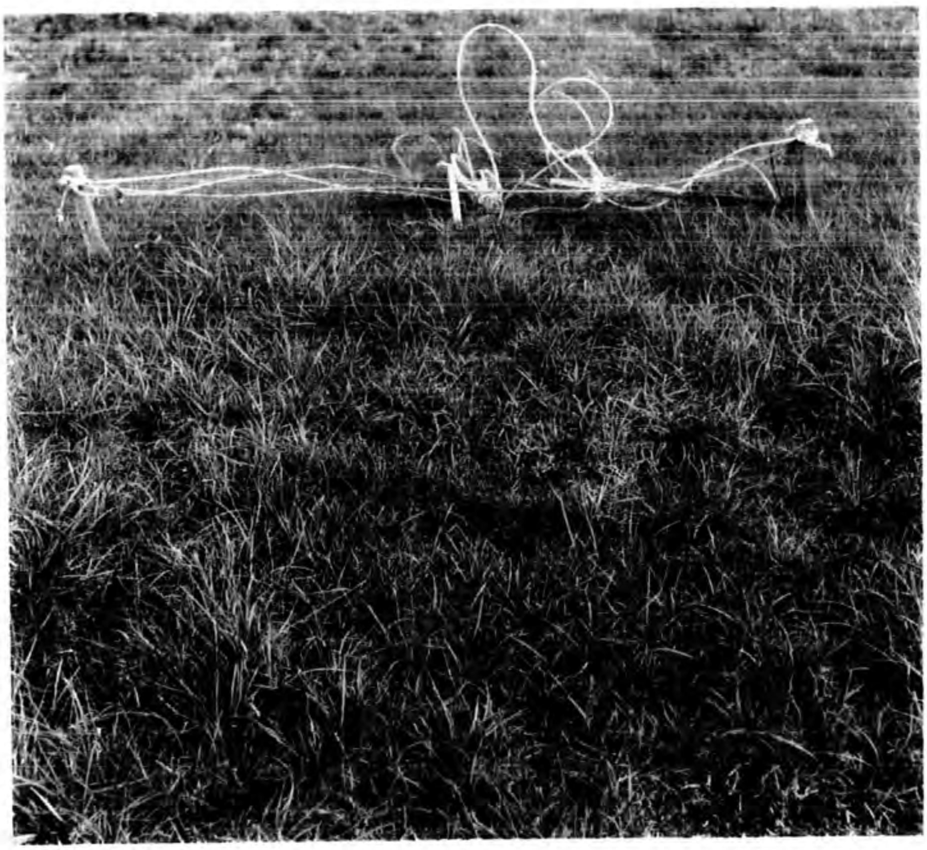


PLATE 5B METALLIFEROUS 'FLUSH' CONTROL AREA

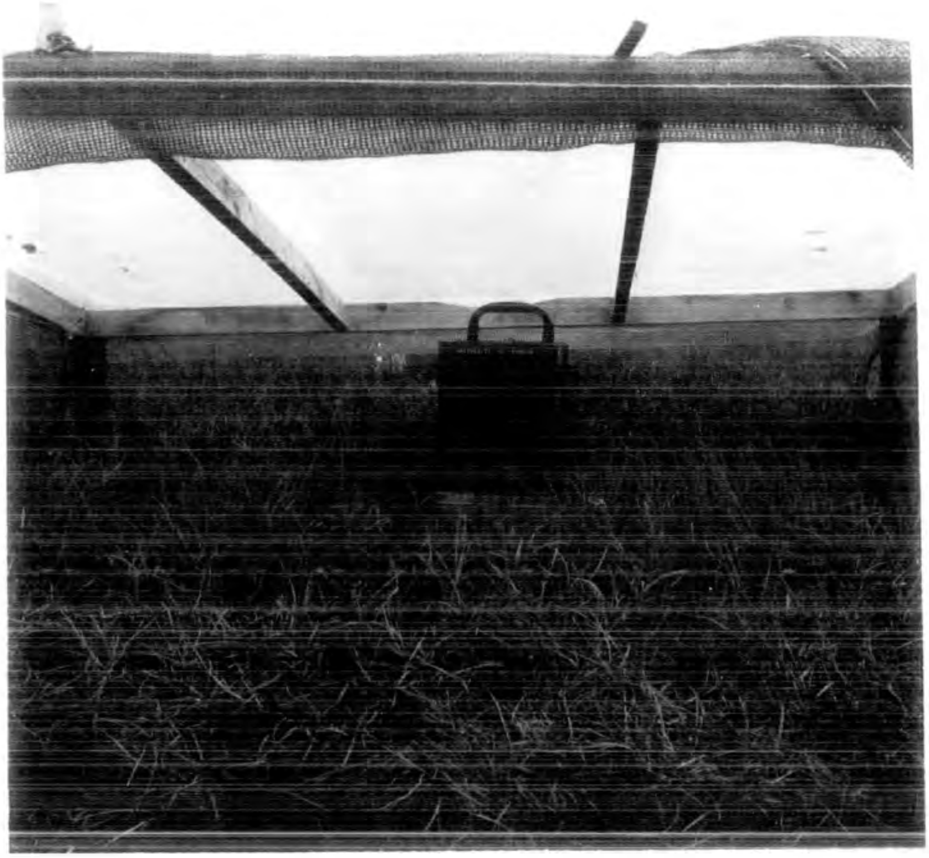


PLATE 6A NON-METALLIFEROUS 'FLUSH' BENEATH COLD FRAME

PLATE 6B NON-METALLIFEROUS 'FLUSH' CONTROL AREA

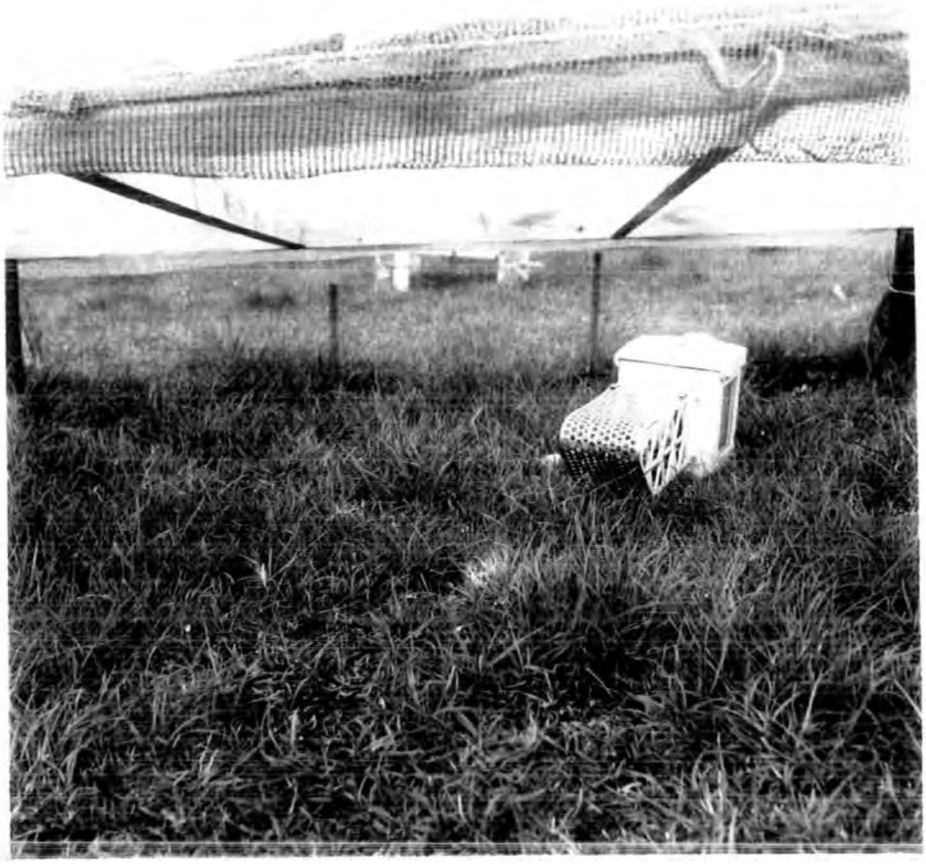


PLATE 7A METALLIFEROUS GRASSLAND BENEATH COLD FRAME

PLATE 7B METALLIFEROUS GRASSLAND CONTROL AREA

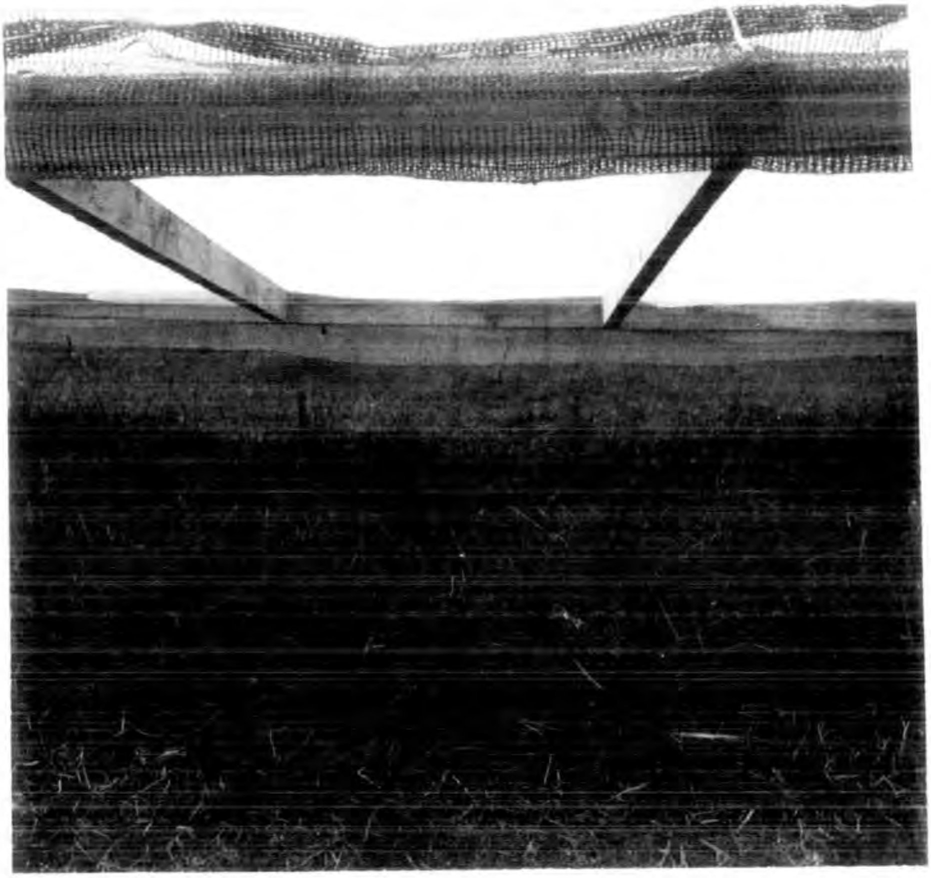


PLATE 8A NON-METALLIFEROUS GRASSLAND BENEATH COLD FRAME

PLATE 8B NON-METALLIFEROUS GRASSLAND CONTROL AREA

APPENDIX A

SOIL AND PLANT ANALYSIS

A. Preparation of plant and soil material for analysis

Plant and soil material to be analysed for total cations and phosphorus content was dried in paper bags for 24 hours at 100°C, and then ground to pass an 80 mesh sieve.

The grinding of plant tissue was carried out mechanically, and the soil by hand in a pestle and mortar.

Soil to be analysed for exchangeable cations, bicarbonate, extractable phosphate, was prepared in a similar way to the soil for total cations, except that drying took three days at 30°C.

B. Total cations in plant and soil material

1g. of the material, prepared as described above, was digested with nitric and perchloric acid following the procedure described by Johnson and Ulricht (1959). Cations were estimated by aspirating the diluted and filtered (Whatman No. 42 filter paper) digest directly into a Perkin Elmer 480 atomic absorption spectophotometer.

C. Total phosphate in soil and plant material

40 ml aliquots of the digest prepared as described above, were mixed with 5 ml of ammonium metavanadate reagent and the colour read at 470 on an Eel flow through spectrophotometer (Kitson & Melton, 1944).

D. Exchangeable cations in soil

1 g. of soil, prepared as described in the first section was shaken with 100 ml normal annonium acetate for an hour, and filtered through Whatman No. 42 filter paper. The cations were estimated by atomic absorption spectrophotometry using a 3 slot burner head because of the high concentration of dissolved solids in the solutions.

E. Available phosphate in soils

Phosperus was extracted with 100 ml sodium bicarbonate by shaking it with 5 g of soil for 30 minutes. 5 ml of the filtrate (Whatman No 40 filter paper) was mixed with ammonium molybdate and stannous chloride reagents as described by Black (1965). The colour was read at 660 on an Eel flow through spectrophotometer.

F. Moisture in soils

10 g of fine earth sample were dried at 30°C, then samples of known weight were placed into weighed silica crucibles, and dried at 105°C for 4 hours. After reweighing, the percentage moisture in the soil was calculated as a percentage of the air dry soil. This does not give moisture holding capacity, but as both soils were dried to 30°C in the same humidity prior to complete drying, it does give a measure of their relative water holding capacities.

G. Loss on ignition from soils

The oven dried soil was ignited in a muffle furnace at 800°C for 2 hours and reweighed. The percentage loss on ignition was calculated as a percentage of the oven dry soil.

H. Soil texture by mechanical analysis (Hydrometer Method)

50 g of 2 mm sieved soil were mixed with water and NaOH in a milk bottle and shaken overnight. Four minutes 48 seconds after transfer to a 1000 ml cylinder the temperature and density of the suspension were recorded in order to obtain an estimate of the percentage sand (international limits). Estimates of the percentage clay were obtained after 2 hours. The percentage silt was found by substraction. Corrections were applied for hydrometer readings and loss on ignition (Bouyoucos, 1936).

I. Soil analysis for mineral content

50 g of 2 mm sieved soil were mixed with water in a milk bottle and shaken overnight. The clay suspension was carefully emptied into a beaker and placed in the oven at 105^{o}C to dry. The dried clay was then ground and used for the identification of the minerals using a PW1130 kilowatt x-ray generator, and x-ray data in the American Service for Testing Materials Index (ASYM ind.). Boehmite standard 10% was used to estimate the amount of quartz. (Brown, G. 1961).

APPENDIX B

STATISTICAL METHODS

(a) For the comparison of soil minerals the t-test for equal and unequal size groups was used with significance idicated as follows:

N.S. = not statistically significant; *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$; ****$p < 0.001$.

(b) To test growth differences of the species in the pot experiments the total leaf length recorded for each pot was transformed into logarithmic form, and the mean log was taken for each sampling date. The logarithmic transformation was made so that for any period of exponential growth the mean log of total leaf length (y) plotted against the number of days growth (x) would give a straight line; also to stabalise the variance. The model for the regression equation is $y = a + bx$, the estimate for b is :

$$b = \frac{\sum (x-\bar{x})\ (y-\bar{y})}{\sum (x-\bar{x})^2} \qquad (1)$$

The gradients of each species growing in two types of soil were compared by a t-test,

where

$$t = \frac{b_1 - b_2}{\sqrt{\dfrac{s_1^2 + s_2^2}{\sum (x-\bar{x})^2}}} \qquad (2)$$

for $n_1 + n_2 - 4$ degrees of freedom where n_1 and n_2 are the number of pairs of observations in each regression; $S_1^{\ 2}$ and $S_2^{\ 2}$ are the variances due to regressions; they are estimated by :

$$S^2 = \frac{\sum(y-\bar{y})^2 - \dfrac{\left[\sum(x-\bar{x})\ (y-\bar{y})\right]^2}{\sum(x-\bar{x})^2}}{n-2} \qquad (3)$$

The formula (2) is a simplified form of :

$$t = \frac{b_1-b_2}{\sqrt{S_p^2\left(\dfrac{1}{\sum_1(x-\bar{x})^2} + \dfrac{1}{\sum_2(x-\bar{x})^2}\right)}} \qquad (4)$$

S_p^2 = pooled variance of the variances S_1^2 and S_2^2 due to regressions :

$$S_p^2 = \frac{(n_1-2)\ \ S_1^2 + (n_2-2)\ \ S_2^2}{n_1+n_2\ -4} \qquad (5)$$

Because $n_1 = n_2 = n$ the (s) becomes

$$S_p^2 = \frac{(n-2)\cdot(S_1^2 + S_2^2)}{2(n-2)} = \frac{(S_1^2 + S_2^2)}{2} \qquad (6)$$

Also because $\sum_1(x-\bar{x})^2 = \sum_2(x-\bar{x})^2 = \sum(x-\bar{x})^2$ (4) becomes :

$$t = \frac{b_1-b_2}{\sqrt{\dfrac{(S_1^2 + S_2^2)}{2} \cdot \dfrac{2}{\sum(x-\bar{x})^2}}} = \frac{b_1-b_2}{\sqrt{\dfrac{S_1^2 + S_2^2}{\sum(x-\bar{x})^2}}} \qquad (2)$$

(c) To test differences in mineral uptake of the species grown in different soils, analysis of variance for samples of equal or unequal size was used.

Analysis of variance with samples of equal size

Source of variation	Sum of squares	Degrees of freedom	Mean square
Total	$\sum\sum X_{ij}^2 - C$	an-1	
Within treatments	$\sum\sum X_{ij} - \sum \frac{X_{i.}^2}{n_i}$	a (n-1)	s^2
Between treatments	$\sum \frac{X_{i.}^2}{n_i} - C$	a-1	s_c^2

a = classes; n = observations; X_{ij} = jth observation from the ith class; $X_{i.}$ = class total of X_{ij}; $\sum X_{i.}$ = the grand total; n_i = size of the sample in the ith class; $\sum n_i$ = N = total size of all samples; $C = \frac{(\sum X_{i.})^2}{\sum n_i}$;

$F = \frac{Sc^2}{S^2}$ for (a-1) and a (n-1) degreesof freedom.

Analysis of variance with samples of unequal size

Source of variation	Sum of squares	Degrees of freedom	Mean square
Total	$\sum\sum X_{ij}^2 - C$	N-1	
Within treatments	$\sum\sum X_{ij} - \sum \frac{X_{i.}^2}{n_i}$	N-a	S^2
Between treatments	$\sum \frac{X_{i.}^2}{n_i} - C$	a-1	S_c^2

The F ratio, $\frac{S_c^2}{S^2}$ has (a-1) and (N-a) d.f, the standard error of the difference between the ith and kth class means, with (N-a) degrees of freedom is :

$$\sqrt{S^2\left(\frac{1}{n_i} + \frac{1}{n_k}\right)}$$

To test the effect of treatments, a comparison of between treatments mean square with the within treatment mean square (residual) was calculated at the 5% and 1% levels. Where the value of F was significant the difference between means was estimated by using the Least Significant Difference (LSD) with significance indicated in section (a)

(d) In the 1974 cold frame experiment the comparisons of growth were based on the comparison of the regression lines of the log of individual weight, or the log of standing crops, on time. The gradients and t-tests calculated as in section (b).

(e) Soil minerals and tissue minerals were compared as in section (c).

Concordance of Rankings

The method makes use of Kendall's coefficient of concordance W. The technique, described in Siegal (1956) is briefly as follows:-

1. Calculate W.

$$W = \frac{S}{\frac{1}{12} K^2 \quad (N^3 - N)}$$

$$S = \left(R_j - \frac{R_j}{N} \right)^2$$

K = number of sets to be ranked

N = number of entities ranked

R_j = sum of ranks for each entity

The null hypothesis is that there is no significant concordance between the ranking. This hypothesis can be tested by calculating as follows :

$$\chi^2 = K(N-1)W$$

This value is compared with values is a table of χ^2 for N-1 degrees of freedom. If the calculated χ^2 exceeds the tabulated χ^2 for any level of significance, that level is the probability of obtaining such a calculated value if the null hypothesis is true, and as such the null hypothesis can be rejected with that level of significance.

APPENDIX C

D A T A T A B L E S

DATA TABLES IN APPENDIX C

Table AP. 1

Exchangeable cations and phosphorus in *Tofieldietalia*

soil from Teesdale and Sunbiggin (mg/g.dry.wt.)

1 g. air dried soil extracted with 100 ml

NH_4 acetate

	Teesdale Core No. 1	2	3	4	$\bar{x}$		Sunbiggin Core No. 1	2	3	4	$\bar{x}$	
Na	.520	.500	.490	.320	.457	± .147	.330	.150	.120	.190	.197	± .147
Mg	1.193	1.033	1.063	.833	1.030	± .237	.943	1.163	.483	.433	.755	± .565
Al	.087	.059	.063	.024	.058	± .041	.016	.055	.004	.027	.025	± .035
K	1.950	2.020	1.530	.840	1.585	± .861	.340	.220	.340	.270	.292	± .093
Ca	86.760	76.860	82.960	75.360	80.485	± 8.459	54.260	32.160	48.960	42.760	44.535	±15.096
Mn	.290	.247	.228	.185	.237	± .069	.135	.066	.068	.148	.104	± .069
Fe	.175	.143	.153	.244	.178	± .072	.023	.034	.025	.150	.058	± .098
Cu	.008	.006	.005	.004	.005	± .002	.009	.003	.005	.007	.006	± .004
Zn	.444	.399	.389	.274	.376	± .115	.026	.011	.003	.009	.012	± .015
Cd	-	.010	.009	.006	.008	± .004	.002	.001	.002	.001	.001	± .001
Pb	.154	.091	.129	.104	.119	± .044	.011	.023	.015	.012	.015	± .009
*P	.007	.006	.009	.009	.008	± .002	.003	.005	.006	.002	.004	± .003

* Extracted with 0.5 m Na HCO_3

cont/

Table AP. 1 (cont.)

Exchangeable cations and phosphorus in Seslerio-

Mesobromion soil from Teesdale and Sunbiggin (mg/g.dry.wt.)

1 g. air dried soil extracted with 100-ml

NH_4 acetate

Teesdale

Core No.

	1	2	3	4	$\bar{x}$		
Na	.220	.240	.240	.140	.210	±	.076
Mg	.463	.413	.363	.393	.408	±	.007
Al	.047	.083	.277	.039	.111	±	.178
K	.940	.910	.770	.720	.835	±	.169
Ca	76.960	81.760	72.160	74.460	76.335	±	6.540
Mn	.087	.098	.139	.079	.101	±	.042
Fe	.060	.105	.342	.049	.139	±	.218
Cu	.004	.005	.006	.004	.005	±	.001
Zn	.144	.194	.229	.139	.176	±	.068
Cd	.006	.006	.006	.005	.006	±	.001
Pb	.178	.174	.228	.144	.181	±	.055
*P	.011	.009	.013	.014	.012	±	.003

Sunbiggin

Core No.

	1	2	3	4	5	6	$\bar{x}$		
Na	.240	.240	.310	.300	.310	.150	.258	±	.066
Mg	.913	.923	1.083	2.083	1.123	.893	1.170	±	.481
Al	.027	.182	.043	.067	.147	.225	.115	±	.085
K	1.150	1.610	.680	1.330	.980	1.200	1.158	±	.332
Ca	45.660	31.060	60.760	32.460	72.460	4.860	41.210	±	25.276
Mn	.072	.950	.018	.380	.034	1.310	.460	±	.576
Fe	.035	.112	.036	.028	.097	.084	.065	±	.039
Cu	.004	.004	.004	.004	.005	.009	.005	±	.002
Zn	.005	.055	.004	.004	.011	.009	.015	±	.021
Cd	.002	.001	.003	.003	.002	.002	.002	±	.001
Pb	.008	.008	.014	.010	.021	.004	.011	±	.006
*P	.011	.010	.007	.009	.008	.009	.009	±	.001

* Extracted with Na HCO_3

Table AP.2

Characteristics of Tofieldietalia soil from Teesdale used in pot culture experiments.

Total cations, total & extractable P (mg/g.dry.wt.),pH.

Teesdale

	sample No. T1	T2	T3	T4	T5	T6	T7	T8	T9	$\bar{x}$		
Na	.322	.358	.322	.482	.478	.322	.302	.292	.372	.361	±	.055
Mg	1.480	1.600	1.470	1.620	1.590	1.210	1.240	1.410	1.160	1.420	±	.136
Al	23.500	27.900	27.500	28.900	29.700	25.200	25.600	25.900	28.800	27.000	±	1.577
K	1.170	1.290	1.130	1.230	1.210	1.090	1.050	1.050	1.310	1.170	±	.075
Ca	12.700	11.600	10.900	11.900	10.700	10.600	9.900	10.400	10.300	11.000	±	.007
Mn	.790	1.500	.950	1.420	1.410	1.610	1.240	.710	1.190	1.202	±	.246
Fe	23.400	25.000	23.900	27.000	32.700	26.900	26.300	25.000	24.000	26.022	±	2.165
Cu	.023	.021	.019	.022	.021	.028	.026	.020	.026	.023	±	.002
Zn	1.170	1.290	1.400	1.390	1.300	1.210	1.280	1.290	1.320	1.294	±	.057
Cd	.015	.013	.015	.016	.013	.013	.015	.014	.018	.015	±	.001
Pb	.550	.600	.630	.670	.640	.650	.600	.590	.620	.617	±	.028
Tot.P	.375	.424	.425	.467	.453	.467	.410	.396	.410	.425	±	.025
Ext.P	.010	.007	.008	.008	.008	.007	.008	.010	.010	.008	±	.001
pH	6.7	6.8	6.6	6.8	6.6	6.6	6.7	6.7	6.6	6.7	±	0.06

% moisture, % loss on ignition and texture* of the above soil

	T1	T2	T3	T4	T5	T6	T7	T8	T9	$\bar{x}$		
Moist.	4.26	3.85	3.85	4.02	3.85	4.10	4.00	4.21	4.42	4.06	±	0.15
l.o.i.	30.05	26.90	26.93	28.29	26.11	28.01	27.31	28.03	28.47	27.78	±	0.88
Sand		74.25	71.06		68.77					71.36	±	6.79
Silt		25.34	28.19		26.83					26.79	±	3.52
Clay		0.41	0.75		4.40					1.85	±	5.46

* Three samples with the lowest loss on ignition were taken.

cont/

Table AP. 2 (cont.)

Characteristics of Tofieldietalia soil from Sunbiggin used in pot experiments.

Total cations, total & extractable P (mg/g.dry.wt.), pH.

Sunbiggin

sample No.

	S1	S2	S3	S4	S5	S6	S7	S8	S9	$\bar{x}$		
Na	.078	.098	.082	.112	.088	.088	.088	.078	.072	.087	±	.004
Mg	1.670	1.720	1.730	1.670	1.680	1.570	1.600	1.580	1.720	1.660	±	.048
Al	10.300	12.200	11.800	11.000	12.800	8.700	10.900	10.000	8.000	10.633	±	1.209
K	1.090	1.210	1.290	1.430	1.110	.950	.870	1.150	.970	1.119	±	.135
Ca	5.180	4.640	5.040	8.970	4.020	6.040	4.520	4.850	5.580	5.426	±	1.115
Mn	.420	.480	.630	.500	.430	.430	.470	.320	.410	.454	±	.064
Fe	7.800	9.500	9.600	9.900	10.800	7.900	8.100	7.600	6.700	8.655	±	1.025
Cu	.015	.012	.011	.014	.010	.012	.015	.013	.010	.012	±	.001
Zn	.097	.082	.099	.096	.102	.130	.098	.083	.100	.099	±	.010
Cd	.002	.002	.002	.002	.003	.003	.003	.003	.002	.002	±	.000
Pb	.059	.056	.056	.066	.051	.061	.069	.048	.052	.058	±	.005
Tot.P	.163	.156	.149	.170	.142	.156	.163	.113	.120	.148	±	.015
Ext.P	.005	.004	.005	.006	.005	.007	.007	.005	.005	.005	±	.000
pH	7.1	7.1	7.3	7.2	7.3	7.4	7.3	7.4	7.4	7.3	±	0.09

% moisture, % loss on ignition and texture* of the above soil

	S1	S2	S3	S4	S5	S6	S7	S8	S9			
Moist.	1.47	1.31	1.50	1.59	1.52	1.43	1.55	1.42	1.45	1.47	±	0.06
l.o.i.	8.73	8.26	9.05	9.29	8.35	8.66	9.55	8.42	7.35	8.62	±	0.49
Sand		87.03			80.96				60.69	76.22	±	34.22
Silt		9.53			12.55				27.58	16.56	±	23.99
Clay		3.44			6.49				11.73	7.22	±	10.4

* Three samples with the lowest loss on ignition were taken.

Table AP.3 Exchangeable cations in soil from sites used in 1974 cold frame experiment

Magnesium

(mg/g.d.wt.)

Repl.no.	Tofieldietalia metallif.	Tofieldietalia non-metallif.	Seslerio-Mesobromion metallif.	Seslerio-Mesobromion non-metallif.
1	.0650	.1200	.0700	.0525
2	.0625	.1350	.0625	.0600
3	.0800	.1325	.0700	.0600
4	.0725	.1200	.0600	.0550
5	.0650	.1625	.0550	.0550
6	.0650	.0875	.0350	.0550
7	.0260	.0900	.0360	.0850
8	.0550	.1100	.0525	.0675
9	.0305	.1200	.0440	.0725
10	.0575	.0700	.0343	.0650
11	.0318	.0925	.0365	.0675
12	.0245	.1100	.0625	.0675
$\bar{x}$	.0529	.1125	.0515	.0635

cont/

Table AP.3 (cont.)

Aluminium

(mg/g.d.wt.)

Repl.no.	Tofieldietalia metallif.	Tofieldietalia non-metallif.	Seslerio-Mesobromion metallif.	Seslerio-Mesobromion non-metallif.
1	.0015	.0115	.0020	.0033
2	.0210	.0045	.0245	.0040
3	.0273	.0260	.0023	.0068
4	.0035	.0468	.0028	.0023
5	.0050	.0068	.0225	.0020
6	.0030	.0108	.0020	.0040
7	.0035	.0155	.0025	.0040
8	.0025	.0155	.0145	.0125
9	.0020	.0160	.0025	.0035
10	.0028	.0140	.0098	.0050
11	.0055	.0110	.0063	.0203
12	.0040	.0068	.0088	.0130
$\bar{x}$	.0068	.0154	.0084	.0067

cont/

Table AP.3 (cont.)

Potassium

(mg/g.d.wt.)

Repl.no.	Tofieldietalia metallif.	Tofieldietalia non-metallif.	Seslerio-Mesobromion metallif.	Seslerio-Mesobromion non-metallif.
1	.0765	.0790	.0990	.0465
2	.0740	.0665	.0865	.0515
3	.1215	.0890	.0940	.0260
4	.0790	.0790	.0565	.0265
5	.0765	.1015	.0740	.1415
6	.0590	.0840	.0320	.0415
7	.0243	.0590	.0790	.0790
8	.0590	.0715	.0390	.0390
9	.0278	.0815	.0540	.0540
10	.0415	.0490	.0270	.0440
11	.0215	.0840	.0440	.0540
12	.0138	.0740	.0740	.0515
$\bar{x}$	.0562	.0765	.0633	.0546

cont/

Table AP.3 (cont.)

Calcium
(mg/g.d.wt.)

Repl.no.	Tofieldietalia metallif.	Tofieldietalia non-metallif.	Seslerio-Mesobromion metallif.	Seslerio-Mesobromion non-metallif.
1	10.23	3.60	11.13	9.63
2	10.93	5.73	10.73	9.95
3	11.25	4.03	10.43	9.83
4	10.50	3.03	10.85	9.40
5	11.50	4.25	11.50	9.30
6	10.35	3.08	9.48	9.85
7	7.95	3.25	8.55	10.65
8	10.00	3.53	8.73	10.45
9	8.38	3.05	9.58	10.25
10	10.15	2.73	9.05	10.28
11	9.00	3.23	8.83	10.15
12	8.30	3.03	10.68	10.25
$\bar{x}$	9.88	3.55	9.96	10.00

cont/

Table AP.3 (cont.)

Iron

(mg/g.d.wt.)

Repl.no.	Tofieldietalia metallif.	Tofieldietalia non-metallif.	Seslerio-Mesobromion metallif.	Seslerio-Mesobromion non-metallif.
1	.0053	.0333	.0040	.0048
2	.0513	.0043	.0350	.0105
3	.0563	.1550	.0040	.0128
4	.0040	.1900	.0023	.0063
5	.0093	.0088	.0333	.0023
6	.0055	.0155	.0038	.0105
7	.0043	.0198	.0023	.0075
8	.0055	.0128	.0208	.0445
9	.0023	.0500	.0030	.0108
10	.0043	.0185	.0143	.0215
11	.0048	.0108	.0083	.0600
12	.0015	.0090	.0138	.0350
$\bar{x}$	.0129	.0440	.0121	.0189

cont/

Table AP.3 (cont.)

Manganese

(mg/g.d.wt.)

Repl.no.	Tofieldietalia metallif.	Tofieldietalia non-metallif	Seslerio-Mesobromion metallif.	Seslerio-Mesobromion non-metallif.
1	.1000	.3000	.0535	.0363
2	.1168	.0843	.0723	.0460
3	.2000	.1950	.0748	.0455
4	.1095	.2525	.0863	.0548
5	.2050	.1675	.0803	.0525
6	.1900	.1700	.0545	.0563
7	.0500	.0805	.0428	.0618
8	.0578	.1750	.0650	.0403
9	.0253	.1095	.0605	.0410
10	.1275	.1875	.0683	.0690
11	.0328	.3725	.0550	.0520
12	.0200	.2250	.0755	.0538
$\bar{x}$	.1029	.1933	.0657	.0508

cont/

Table AP.3 (cont.)

Zinc
(mg/g.d.wt.)

Repl.no.	Tofieldietalia metallif.	Tofieldietalia non-metallif.	Seslerio-Mesobromion metallif.	Seslerio-Mesobromion non-metallif.
1	.1786	.0261	.0238	.0123
2	.1786	.0586	.0288	.0143
3	.2236	.0311	.0276	.0158
4	.1911	.0293	.0263	.0183
5	.1961	.0258	.0333	.0168
6	.1786	.0426	.0146	.0168
7	.1561	.0576	.0136	.0196
8	.1936	.0668	.0191	.0131
9	.0716	.0318	.0131	.0126
10	.1586	.0446	.0198	.0181
11	.0848	.0318	.0173	.0198
12	.0728	.0356	.0401	.0161
$\bar{x}$	.1570	.0401	.0231	.0161

cont/

Table AP.3 (cont.)

Lead

(mg/g.d.wt.)

Repl.no.	Tofieldietalia metallif.	Tofieldietalia non-metallif.	Seslerio-Mesobromion metallif.	Seslerio-Mesobromion non-metallif.
1	.1363	.0215	.0085	.0303
2	.0763	.0588	.0140	.0375
3	.0513	.0203	.0115	.0425
4	.1338	.0193	.0153	.0513
5	.0863	.0178	.0105	.0473
6	.1838	.0513	.3363	.0485
7	.0888	.0813	.4138	.0375
8	.1288	.0838	.2488	.0343
9	.1488	.0713	.3085	.0290
10	.1563	.0638	.2563	.0488
11	.2563	.0293	.4513	.0433
12	.1638	.0428	.0145	.0458
$\bar{x}$	.1342	.0468	.1741	.0413

cont/

Table AP.3 (cont.)

Extractable
Phosphorus
(mg/g.d.wt.)

Repl.no.	Tofieldietalia metallif.	Tofieldietalia non-metallif.	Seslerio-Mesobromion metallif.	Seslerio-Mesobromion non-metallif.
1	.0140	.0212	.0184	.0116
2	.0094	.0136	.0212	.0160
3	.0280	.0112	.0178	.0116
4	.0158	.0174	.0136	.0108
5	.0176	.0148	.0108	.0080
6	.0172	.0218	.0106	.0092
7	.0116	.0112	.0190	.0192
8	.0282	.0190	.0144	.0170
9	.0152	.0184	.0180	.0136
10	.0110	.0160	.0110	.0130
11	.0196	.0280	.0174	.0096
12	.0100	.0252	.0124	.0100
$\bar{x}$	.0165	.0182	.0154	.0125

Table AP.4 Element concentration in live leaves and roots of C. panicea collected in Teesdale and Sunbiggin

	Repl.No.	Magnesium Tees.	Magnesium Sunb.	Aluminium Tees.	Aluminium Sunb.	Potassium Tees.	Potassium Sunb.	Calcium Tees.	Calcium Sunb.	Iron Tees.	Iron Sunb.
in leaves	1	.545	.720	.147	.124	10.15	10.40	4.77	4.41	.625	.345
	2	.595	.740	.179	.122	10.65	10.75	5.60	4.85	.730	.335
	3	.585	.705	.139	.113	10.50	10.30	5.07	4.07	.625	.330
	4	.565	.775	.183	.268	10.10	11.00	5.80	5.20	.840	.585
	5	.570	.765	.175	.232	9.35	10.90	5.15	4.67	.780	.490
	6	.520	.810	.102	.181	9.55	10.95	3.81	5.39	.525	.580
	$\bar{x}$	.563	.753	.154	.173	10.05	10.72	5.03	4.76	.688	.444
in roots	1	.410	.620	.836	1.651	3.36	3.77	9.00	5.85	8.990	8.640
	2	.400	.650	.606	1.546	3.64	4.36	6.40	5.63	8.090	6.590
	3	.415	.615	.701	.946	3.63	4.40	7.60	4.65	9.290	5.090
	4	.460	.695	1.051	1.416	3.26	4.46	9.80	5.55	10.840	6.740
	5	.475	.705	1.271	1.716	2.87	4.23	11.25	5.90	12.240	8.440
	6	.615	.695	1.546	1.431	2.97	4.29	15.50	5.60	14.440	7.290
	$\bar{x}$	.463	.663	1.002	1.451	3.29	4.25	9.93	5.53	10.648	7.132

cont/

AP.4 (cont.)

	Repl.No.	Manganese Tees.	Manganese Sunb.	Zinc Tees.	Zinc Sunb.	Lead Tees.	Lead Sunb.	Cadmium Tees.	Cadmium Sunb.	Phosphorus Tees.	Phosphorus Sunb.
in leaves	1	.226	.345	.137	.045	.0815	.0425	.0012	.0006	.600	.613
	2	.248	.343	.168	.072	.1090	.0430	.0012	.0008	.640	.661
	3	.233	.333	.136	.046	.0880	.0360	.0011	.0005	.621	.587
	4	.250	.363	.174	.097	.1790	.0745	.0012	.0008	.600	.642
	5	.240	.348	.148	.068	.1545	.0445	.0012	.0009	.569	.634
	6	.208	.393	.114	.098	.0720	.0790	.0012	.0006	.561	.658
	$\bar{x}$	.234	.354	.146	.071	.1140	.0533	.0012	.0007	.599	.633
in roots	1	1.150	.805	.464	.197	.2450	.0970	.0047	.0018	.320	.431
	2	.975	.690	.415	.181	.2100	.0650	.0042	.0016	.330	.459
	3	1.050	.545	.450	.116	.2450	.0475	.0048	.0012	.338	.482
	4	1.150	.670	.492	.142	.1350	.0640	.0054	.0014	.333	.482
	5	1.275	.815	.499	.198	.0800	.0910	.0064	.0013	.317	.464
	6	1.475	.720	.540	.144	.0500	.0625	.0081	.0015	.320	.449
	$\bar{x}$	1.179	.708	.477	.163	.1608	.0712	.0056	.0015	.326	.461

Table AP.5 Concentrations of certain elements in plant tissues at the end of the pot experiment. (excluding barley)

Magnesium

(mg/g.d.wt.)

a) In live leaves

Repl. No.	C.panicea Ts	C.panicea Ss	C.ledidocrp. Ts	C.ledidocrp. Ss	E.latifol. Ts	E.latifol. Ss	S.nigricans Ts	S.nigricans Ss	T.pusilla Ts	T.pusilla Ss
1	1.26	1.24	1.22	.79	1.24	1.05	1.25	1.85	1.09	1.21
2	1.11	.41	1.12	.91	1.02	.97	1.40	1.65	1.15	1.15
3	1.60	1.09	1.25	1.04	1.11	.95	1.43	1.60	.96	1.09
4	1.75	1.09	1.05	.94	1.28	1.00	-	-	-	-
5	2.13	1.21	1.17	.82	1.51	.97	-	-	-	-
$\bar{x}$	1.57	1.01	1.16	.90	1.23	.99	1.36	1.70	1.07	1.15

b) In live roots

Repl. No.	C.panicea Ts	C.panicea Ss	C.ledidocrp. Ts	C.ledidocrp. Ss	E.latifol. Ts	E.latifol. Ss	S.nigricans Ts	S.nigricans Ss	T.pusilla Ts	T.pusilla Ss
1	1.09	1.08	1.60	1.74	1.07	1.39	.70	.83	1.18	1.36
2	1.05	1.35	1.39	1.77	1.16	1.33	.68	.83	1.27	1.36
3	1.09	.96	1.39	1.70	.99	1.37	.73	.83	1.15	1.46
4	1.05	1.17	1.48	1.82	1.34	1.26	-	-	-	-
5	1.07	1.39	1.66	1.91	1.16	1.22	-	-	-	-
$\bar{x}$	1.07	1.19	1.50	1.79	1.14	1.31	.70	.83	1.20	1.39

cont/

Table AP.5 (cont.)

<u>Aluminium</u>

(mg/g.d.wt.)

a) In live leaves

Repl. No.	C.panicea		C.ledidocrp.		E.latifol.		S.nigricans		T.pusilla	
	Ts	Ss	Ts	Ss	Ts	Ss	Ts	Ss	Ts	Ss
1	.21	.66	1.71	1.01	.19	.19	.77	.18	1.13	1.84
2	.10	.10	.80	1.53	.33	.32	.57	.10	1.35	.92
3	.29	.38	1.31	1.53	.31	.20	.49	.08	1.18	.70
4	.21	.23	1.21	.65	.36	.37	-	-	-	-
5	.22	.23	1.01	1.02	.55	.33	-	-	-	-
$\bar{x}$	.21	.32	1.21	1.15	.35	.28	.61	.12	1.22	1.15

b) In live roots

Repl. No.	C.panicea		C.ledidocrp.		E.latifol.		S.nigricans		T.pusilla	
	Ts	Ss	Ts	Ss	Ts	Ss	Ts	Ss	Ts	Ss
1	3.04	2.57	2.69	3.25	4.55	3.01	5.47	3.04	7.49	4.98
2	3.22	3.52	1.79	2.75	5.51	2.86	4.30	2.02	8.98	4.92
3	4.13	1.70	2.19	3.69	4.25	3.34	4.75	2.49	5.91	3.49
4	3.62	2.79	3.22	5.61	5.91	2.58	-	-	-	-
5	2.25	2.36	3.95	4.39	6.57	3.36	-	-	-	-
$\bar{x}$	3.25	2.59	2.77	3.94	5.36	3.03	4.84	2.52	7.46	4.46

cont/

Table AP.5 (cont.)

Potassium

(mg/g.d.wt.)

a) In live leaves

Repl. No.	C.panicea Ts	C.panicea Ss	C.ledidocrp. Ts	C.ledidocrp. Ss	E.latifol. Ts	E.latifol. Ss	S.nigricans Ts	S.nigricans Ss	T.pusilla Ts	T.pusilla Ss
1	8.76	18.45	12.16	11.90	9.27	10.46	6.38	11.63	6.98	6.67
2	9.10	6.55	12.29	8.00	9.10	9.61	6.63	10.13	7.60	8.22
3	13.52	17.09	11.64	11.51	9.78	8.59	6.13	9.63	5.43	7.60
4	16.07	13.52	12.16	10.34	10.63	8.08	-	-	-	-
5	14.88	15.56	12.29	11.25	10.80	9.10	-	-	-	-
$\bar{x}$	12.47	14.23	12.11	10.60	9.92	9.17	6.38	10.46	6.67	7.50

b) In live roots

Repl. No.	C.panicea Ts	C.panicea Ss	C.ledidocrp. Ts	C.ledidocrp. Ss	E.latifol. Ts	E.latifol. Ss	S.nigricans Ts	S.nigricans Ss	T.pusilla Ts	T.pusilla Ss
1	3.71	3.58	4.62	3.45	5.53	5.92	1.70	3.66	3.75	4.28
2	4.10	3.97	3.84	3.58	4.36	5.92	2.57	3.66	2.67	4.00
3	5.01	3.71	4.49	3.32	3.19	5.40	.87	3.49	3.75	5.05
4	4.49	3.71	4.62	3.97	5.40	5.40	-	-	-	-
5	4.10	3.19	4.62	3.45	3.71	4.10	-	-	-	-
$\bar{x}$	4.28	3.63	4.44	3.55	4.44	5.35	1.71	3.60	3.39	4.44

cont/

Table AP.5 (cont.)

Calcium

(mg/g.d.wt.)

a) In live leaves

Repl. No.	C.panicea Ts	C.panicea Ss	C.ledidocrp. Ts	C.ledidocrp. Ss	E.latifol. Ts	E.latifol. Ss	S.nigricans Ts	S.nigricans Ss	T.pusilla Ts	T.pusilla Ss
1	-	8.46	6.89	3.82	8.51	8.68	-	10.89	14.68	14.19
2	-	2.71	-	-	6.22	6.23	8.59	9.22	20.17	-
3	6.66	6.71	6.07	-	7.24	5.91	8.14	8.97	14.81	15.74
4	6.64	5.89	-	5.09	8.22	-	-	-	-	-
5	9.14	7.00	6.26	-	7.25	5.79	-	-	-	-
$\bar{x}$	7.48	6.15	6.41	4.46	7.49	6.65	8.37	9.69	16.55	14.97

b) In live roots

Repl. No.	C.panicea Ts	C.panicea Ss	C.ledidocrp. Ts	C.ledidocrp. Ss	E.latifol. Ts	E.latifol. Ss	S.nigricans Ts	S.nigricans Ss	T.pusilla Ts	T.pusilla Ss
1	-	4.40	3.60	3.38	3.75	3.43	-	11.27	7.28	6.93
2	4.52	4.39	2.75	3.86	5.90	4.69	9.38	13.14	7.74	6.13
3	4.47	4.40	3.42	-	5.77	3.70	21.96	11.04	8.02	7.18
4	4.00	4.08	-	4.22	7.06	4.56	-	-	-	-
5	3.56	3.84	-	4.23	5.51	6.15	-	-	-	-
$\bar{x}$	4.14	4.22	3.26	3.92	5.60	4.51	15.67	11.82	7.68	6.75

cont/

Table AP.5 (cont.)

Iron

(mg/g.d.wt.)

a) In live leaves

Repl. No.	C.panicea Ts	C.panicea Ss	C.ledidocrp. Ts	C.ledidocrp. Ss	E.latifol. Ts	E.latifol. Ss	S.nigricans Ts	S.nigricans Ss	T.pusilla Ts	T.pusilla Ss
1	.31	.68	1.49	1.05	.24	.33	.78	.28	1.02	1.69
2	.18	.19	.75	1.78	.44	.48	.90	.31	1.73	.98
3	.38	.51	1.30	1.58	.32	.27	.62	.21	1.14	.86
4	.26	.32	1.01	.63	.38	.35	-	-	-	-
5	.37	.34	.99	1.05	.68	.49	-	-	-	-
$\bar{x}$	.30	.41	1.11	1.22	.41	.38	.77	.27	1.30	1.18

b) In live roots

Repl. No.	C.panicea Ts	C.panicea Ss	C.ledidocrp. Ts	C.ledidocrp. Ss	E.latifol. Ts	E.latifol. Ss	S.nigricans Ts	S.nigricans Ss	T.pusilla Ts	T.pusilla Ss
1	3.49	4.39	3.59	3.79	3.34	2.69	4.14	3.48	5.20	4.43
2	7.68	4.81	2.03	3.59	4.68	2.29	4.79	2.43	6.81	4.36
3	4.27	4.01	2.48	3.01	4.00	3.51	6.13	2.58	5.14	3.06
4	4.95	4.60	3.75	4.56	5.84	2.49	-	-	-	-
5	7.02	3.17	3.99	3.47	4.48	2.60	-	-	-	-
$\bar{x}$	5.48	4.20	3.17	3.68	4.47	2.72	5.02	2.83	5.72	3.95

cont/

Table AP.5 (cont.)

Zinc

(mg/g.d.wt.)

a) In live leaves

Repl. No.	C.panicea Ts	C.panicea Ss	C.ledidocrp. Ts	C.ledidocrp. Ss	E.latifol. Ts	E.latifol. Ss	S.nigricans Ts	S.nigricans Ss	T.pusilla Ts	T.pusilla Ss
1	.112	.092	.107	.033	.148	.037	.113	.058	.130	.099
2	.117	.036	.088	.036	.146	.061	.110	.050	.102	.158
3	.230	.138	.133	.095	.121	.141	.103	.063	.146	.499
4	.175	.088	.103	.036	.145	.044	-	-	-	-
5	.218	.107	.103	.031	.126	.046	-	-	-	-
$\bar{x}$	.170	.092	.107	.046	.137	.066	.109	.057	.126	.252

b) In live roots

Repl. No.	C.panicea Ts	C.panicea Ss	C.ledidocrp. Ts	C.ledidocrp. Ss	E.latifol. Ts	E.latifol. Ss	S.nigricans Ts	S.nigricans Ss	T.pusilla Ts	T.pusilla Ss
1	.280	.073	.224	.056	.377	.070	.313	.078	.570	.174
2	.213	.077	.137	.046	.341	.085	.284	.092	.645	.152
3	.282	.059	.161	.056	.351	.065	.274	.068	.446	.130
4	.259	.072	.225	.064	.387	.064	-	-	-	-
5	.581	.108	.298	.060	.426	.061	-	-	-	-
$\bar{x}$	.323	.078	.209	.056	.376	.069	.290	.079	.554	.152

cont/

Table AP.5 (cont.)

Cadmium

(mg/g.d.wt.)

a) In live leaves

Repl. No.	C.panicea Ts	C.panicea Ss	C.ledidocrp. Ts	C.ledidocrp. Ss	E.latifol. Ts	E.latifol. Ss	S.nigricans Ts	S.nigricans Ss	T.pusilla Ts	T.pusilla Ss
1	.0027	.0012	.0018	.0005	.0009	.0012	.0018	.0010	.0078	.0034
2	.0031	.0009	.0022	.0008	.0009	.0007	.0023	.0013	.0022	.0028
3	.0036	.0022	.0027	.0005	.0010	.0010	.0015	.0013	.0047	.0019
4	.0039	.0019	.0029	.0009	.0007	.0002	-	-	-	-
5	.0048	.0012	.0030	.0008	.0012	.0032	-	-	-	-
$\bar{x}$	.0036	.0015	.0025	.0007	.0009	.0013	.0019	.0012	.0049	.0027

b) In live roots

Repl. No.	C.panicea Ts	C.panicea Ss	C.ledidocrp. Ts	C.ledidocrp. Ss	E.latifol. Ts	E.latifol. Ss	S.nigricans Ts	S.nigricans Ss	T.pusilla Ts	T.pusilla Ss
1	.0125	.0025	.0104	.0017	.0142	.0017	.0048	.0014	.0105	.0028
2	.0086	.0031	.0086	.0014	.0112	.0017	.0065	.0014	.0087	.0023
3	.0098	.0023	.0091	.0017	.0113	.0017	.0031	.0015	.0121	.0022
4	.0125	.0014	.0105	.0025	.0189	.0014	-	-	-	-
5	.0112	.0026	.0130	.0021	.0150	.0013	-	-	-	-
$\bar{x}$	.0109	.0024	.0103	.0019	.0141	.0016	.0048	.0014	.0104	.0026

cont/

Table AP.5 (cont.)

Lead
(mg/g.d.wt.)

a) In live leaves

Repl. No.	C.panicea		C.ledidocrp.		E.latifol.		S.nigricans		T.pusilla	
	Ts	Ss	Ts	Ss	Ts	Ss	Ts	Ss	Ts	Ss
1	.0051	.0544	.0572	.0325	.0119	.0119	.0300	.0100	.0279	.0217
2	.0323	.0102	.0793	.0273	.0238	.0017	.0225	.0050	.0186	.0124
3	.0068	.0068	.0468	.0221	.0068	.0085	.0225	.0050	.0558	.0093
4	.0085	.0170	.0260	.0351	.0119	.0068	-	-	-	-
5	.0204	.0119	.0260	.0520	.0153	.0102	-	-	-	-
$\bar{x}$	.0146	.0201	.0471	.0338	.0139	.0078	.0250	.0067	.0341	.0145

b) In live roots

Repl. No.	C.panicea		C.ledidocrp.		E.latifol.		S.nigricans		T.pusilla	
	Ts	Ss	Ts	Ss	Ts	Ss	Ts	Ss	Ts	Ss
1	.0832	.0546	.0910	.0403	.1040	.0208	.1207	.0306	.1705	.0651
2	.0988	.0442	.0480	.0338	.1261	.0273	.1649	.0238	.1736	.0620
3	.0988	.0520	.0936	.0273	.1027	.0234	.1105	.0238	.1426	.1426
4	.1131	.0312	.1183	.0351	.1378	.0182	-	-	-	-
5	.0793	.0260	.1404	.0312	.1222	.0247	-	-	-	-
$\bar{x}$	.0946	.0416	.0983	.0335	.1186	.0229	.1320	.0261	.1622	.0899

cont/

Table AP.5 (cont.)

Phosphorus

(mg/g.d.wt.)

a) In live leaves

Repl. No.	C.panicea		C.ledidocrp.		E.latifol.		S.nigricans		T.pusilla	
	Ts	Ss	Ts	Ss	Ts	Ss	Ts	Ss	Ts	Ss
1	.799	1.003	1.235	.611	.833	.833	.850	.900	1.364	1.085
2	.850	1.649	1.066	1.157	.816	1.020	1.050	.850	1.767	1.240
3	1.020	.901	1.105	.455	.816	.867	.900	.800	1.395	1.209
4	1.105	.833	1.144	.663	1.156	.884	-	-	-	-
5	1.207	.850	1.183	.923	1.309	1.054	-	-	-	-
$\bar{x}$	.996	1.047	1.147	.762	.986	.932	.933	.850	1.509	1.178

b) In live roots

Repl. No.	C.panicea		C.ledidocrp.		E.latifol.		S.nigricans		T.pusilla	
	Ts	Ss	Ts	Ss	Ts	Ss	Ts	Ss	Ts	Ss
1	1.94	.546	.624	.780	.689	.611	.442	.697	1.271	.961
2	1.95	1.079	.260	.962	.858	.663	.544	.544	1.767	1.054
3	1.92	.858	.507	1.183	.624	.988	.476	.527	1.209	1.550
4	1.30	1.066	.832	.923	.663	.689	-	-	-	-
5	1.57	1.170	1.326	.884	1.209	.871	-	-	-	-
$\bar{x}$	1.736	.944	.710	.946	.809	.764	.487	.589	1.416	1.188

cont/

Table AP.6 Concentration of certain elements in leaves of barley at the end of pot experiment

Magnesium (mg/g.d.wt.)

Repl.No.	at Teesdale Ts	at Teesdale Ss	at Durham Ts	at Durham Ss
1	1.43	1.55	.96	1.15
2	1.61	1.64	1.21	1.21
3	1.61	1.43	1.24	1.24
4	1.58	1.55	1.27	1.15
5	1.61	1.71	1.15	1.24
6	1.15	1.07	1.32	1.15
7	1.33	1.05	1.42	1.48
8	1.22	1.18	1.03	1.12
$\bar{x}$	1.44	1.40	1.20	1.22

Aluminium (mg/g.d.wt.)

Repl.No.	at Teesdale Ts	at Teesdale Ss	at Durham Ts	at Durham Ss
1	.50	.43	.35	.18
2	.36	.17	.16	.17
3	.55	.33	.41	.18
4	.42	.26	.37	.21
5	.35	.21	.55	.29
6	1.08	1.10	.45	1.03
7	2.02	1.27	.52	1.22
8	1.57	1.28	.90	.75
$\bar{x}$	.86	.63	.46	.50

Potassium (mg/g.d.wt.)

Repl.No.	at Teesdale Ts	at Teesdale Ss	at Durham Ts	at Durham Ss
1	18.14	21.55	15.04	20.31
2	19.28	24.03	17.52	18.14
3	16.90	16.28	15.97	19.38
4	15.04	20.00	16.90	16.90
5	15.97	21.24	19.38	15.97
6	8.12	7.37	7.68	10.35
7	7.02	9.80	7.62	10.53
8	7.97	8.68	6.22	8.68
$\bar{x}$	13.57	16.12	13.29	15.03

cont/

Table AP.6 (cont.)

Calcium
(mg/g.d.wt.)

Repl.No.	at Teesdale Ts	Ss	at Durham Ts	Ss
1	9.04	8.48	8.36	8.45
2	10.34	8.79	9.41	9.23
3	9.79	8.79	11.34	8.21
4	10.28	8.11	9.76	7.52
5	10.07	9.20	8.42	9.04
6	9.80	8.66	9.45	8.48
7	9.90	8.67	9.46	8.49
8	10.00	8.68	9.47	8.50
$\bar{x}$	9.9	8.67	9.46	8.49

Iron
(mg/g.d.wt.)

1	.61	.61	.64	.27
2	.39	.37	.37	.31
3	.58	.65	.53	.29
4	.59	.49	.42	.31
5	.49	.54	.66	.35
6	1.53	1.16	.76	1.37
7	1.99	1.44	.80	1.91
8	1.76	1.34	1.76	1.14
$\bar{x}$	.99	.83	.74	.74

Zinc
(mg/g.d.wt.)

1	.152	.081	.161	.053
2	.130	.081	.105	.056
3	.152	.109	.118	.090
4	.133	.071	.164	.081
5	.155	.065	.164	.105
6	.527	.287	.100	.060
7	.582	.413	.088	.062
8	.572	.365	.142	.063
$\bar{x}$	.300	.184	.130	.071

cont/

Table AP.6 (cont.)

Cadmium
(mg/g.d.wt.)

Repl.No.	at Teesdale Ts	Ss	at Durham Ts	Ss
1	.0078	.0003	.0009	.0003
2	.0028	.0006	.0012	.0003
3	.0012	.0009	.0003	.0003
4	.0006	.0006	.0003	.0006
5	.0009	.0006	.0006	.0006
6	.0097	.0017	.0015	.0005
7	.0048	.0013	.0013	.0007
8	.0042	.0013	.0013	.0008
$\bar{x}$	.0040	.0009	.0009	.0005

Lead
(mg/g.d.wt.)

Repl.No.	at Teesdale Ts	Ss	at Durham Ts	Ss
1	.0279	.0124	.0186	.0093
2	.0279	.0124	.0248	.0124
3	.0310	.0124	.0155	.0155
4	.0806	.0186	.0279	.0124
5	.0248	.0341	.0279	.0155
6	.0533	.0233	.0200	.0250
7	.0817	.0333	.0183	.0167
8	.0633	.0333	.0367	.0150
$\bar{x}$	.0488	.0225	.0237	.0152

Phosphorus
(mg/g.d.wt.)

Repl.No.	at Teesdale Ts	Ss	at Durham Ts	Ss
1	1.395	1.550	1.736	1.147
2	1.147	1.488	1.426	1.085
3	1.488	1.178	1.457	1.178
4	1.240	1.023	1.209	1.054
5	1.550	1.209	1.643	.930
6	1.050	.983	1.483	.850
7	1.333	1.017	1.167	1.217
8	.950	1.117	1.250	.833
$\bar{x}$	1.269	1.196	1.421	1.037

TABLE AP.7

Concentrations of certain elements in Seslerio-Mesobromion vegetation from inside and outside the cold frames at Teesdale in 1973

Inside (μg/g.d.wt.)

	clipped quadrat No. 1	2	3	4	5	$\bar{x}$
Mg	805.0	865.0	845.0	985.0	935.0	887.0 ± 89.6
Al	58.0	62.0	40.0	62.0	46.0	53.6 ± 12.4
Ca	5890.0	7060.0	7870.0	8080.0	7000.0	7180.0 ± 1074.7
Mn	113.5	113.5	206.5	80.5	134.5	129.7 ± 58.3
Fe	157.0	180.0	96.0	234.0	132.0	159.8 ± 64.3
Cu	33.7	46.7	38.7	52.7	32.7	40.9 ± 10.6
Zn	87.7	116.7	75.7	108.7	78.7	93.5 ± 22.6
Cd	0.8	1.7	1.7	1.4	1.8	1.5 ± 0.5
Pb	37	40	57	37	37	41.6 ± 10.8
P	690.0	677.0	828.0	789.0	782.0	753.0 ± 81.9

Outside (μg/g.d.wt.)

	1	2	3	4	5	$\bar{x}$
Mg	755.0	685.0	625.0	745.0	855.0	733.0 ± 106.5
Al	176.0	144.0	181.0	274.0	200.0	195.0 ± 60.2
Ca	6340.0	6660.0	6070.0	5990.0	6190.0	6250.0 ± 328.4
Mn	137.5	157.5	138.5	127.5	98.5	131.9 ± 26.7
Fe	327.0	269.0	959.0	349.0	398.0	460.0 ± 350.9
Cu	46.7	95.7	86.7	41.7	106.7	75.5 ± 36.6
Zn	123.7	164.7	122.7	113.7	133.7	131.7 ± 163.5
Cd	2.1	1.9	3.1	1.9	1.9	2.2 ± 0.6
Pb	51	211	77	51	60	90 ± 85.1
P	789.0	684.0	736.0	809.0	789.0	761.0 ± 63.3

Table AP8 Concentration of certain elements in the vegetation at the end of the 1974 cold frame experiments.

Tofieldietalia

Replicate No.	Magnesium (mg/g.d.wt) Metalliferous uncovered	Magnesium Metalliferous covered	Magnesium Non-metalliferous uncovered	Magnesium Non-metalliferous covered	Aluminium (mg/g.d.wt) Metalliferous uncovered	Aluminium Metalliferous covered	Aluminium Non-metalliferous uncovered	Aluminium Non-metalliferous covered
1	.560	.795	.990	.875	.064	.188	.050	.037
2	.505	.815	.920	.870	.090	.089	.088	.081
3	.625	.710	.825	1.205	.076	.092	.063	.026
4	.585	.580	.700	.830	.090	.092	.107	.039
5	.520	.860	1.035	1.010	.081	.073	.028	.036
6	.790	.675	.825	.880	.055	.074	.069	.086
7	.635	.960	.865	.915	.069	.044	.043	.030
8	.835	.785	.785	.860	.079	.076	.079	.057
9	.530	.705	1.005	1.015	.054	.087	.056	.029
10	.525	.680	.825	1.030	.077	.074	.056	.057
11	.510	.895	.845	1.015	.093	.070	.037	.035
12	.590	.890	.700	.855	.096	.102	.065	.045
$\bar{X}$	.601	.780	.861	.947	.077	.089	.062	.047

LSD for any pair of means (Magnesium)

p	0.1	0.05	0.01	0.001
LSD	.75	.90	.121	.158

LSD for any pair of means (Aluminium)

p	0.1	0.05	0.01	0.001
LSD	.016	.019	.026	.034

cont/

Table AP8 (cont.)

Tofieldietalia

Replicate No.	Potassium (mg/g.d.wt) Metalliferous uncovered	Metalliferous covered	Non-metalliferous uncovered	Non-metalliferous covered	Calcium (mg/g.d.wt) Metalliferous uncovered	Metalliferous covered	Non-metalliferous uncovered	Non-metalliferous covered
1	10.95	10.10	10.15	11.85	6.26	7.31	4.02	3.67
2	10.45	12.70	8.75	10.35	6.94	7.21	3.40	3.41
3	8.50	9.95	11.60	11.00	6.34	6.49	3.72	4.13
4	9.00	9.35	9.75	8.95	7.19	6.90	4.90	3.10
5	10.10	11.35	10.50	9.60	5.82	7.04	3.63	3.63
6	11.60	12.15	8.65	7.25	6.87	6.68	3.52	2.72
7	10.90	8.95	10.60	11.00	6.37	6.61	4.01	3.91
8	10.60	11.10	8.80	9.35	7.39	6.68	2.96	3.70
9	9.35	10.15	9.60	11.50	6.16	6.67	4.53	3.86
10	9.85	11.00	8.70	9.70	5.95	7.10	3.11	3.28
11	9.40	9.05	10.95	11.60	5.52	5.39	3.88	3.76
12	9.30	10.20	9.10	9.60	6.66	7.53	3.39	3.11
$\bar{x}$	10.00	10.50	9.76	10.15	6.46	6.80	3.76	3.52

LSD for any pair of means (Potassium)

p	0.1	0.05	0.01	0.001
LSD	.77	.92	1.23	1.61

LSD for any pair of means (Calcium)

p	0.1	0.05	0.01	0.001
LSD	.36	.43	.58	.75

cont/

Table AP8 (cont.)

Tofieldietalia

Replicate No.	Iron (mg/g.d.wt) Metalliferous uncovered	covered	Non-metalliferous uncovered	covered	Manganese (mg/g.d.wt) Metalliferous uncovered	covered	Non-metalliferous uncovered	covered
1	.133	.193	.175	.145	.179	.193	.408	.353
2	.170	.170	.155	.175	.145	.149	.388	.293
3	.183	.218	.135	.130	.151	.177	.263	.328
4	.155	.175	.170	.105	.134	.123	.225	.338
5	.168	.148	.135	.175	.187	.141	.293	.289
6	.110	.125	.155	.180	.173	.099	.283	.278
7	.148	.183	.165	.120	.201	.186	.258	.298
8	.140	.160	.160	.150	.172	.148	.278	.318
9	.123	.183	.165	.125	.167	.176	.488	.308
10	.115	.170	.160	.160	.153	.109	.363	.363
11	.173	.163	.145	.140	.161	.159	.313	.358
12	.150	.190	.125	.130	.137	.129	.293	.290
$\bar{x}$	.147	.173	.154	.145	.163	.149	.321	.318

LSD for any pair of means (Iron)

p	0.1	0.05	0.01	0.001
LSD	.015	.018	.024	.032

LSD for any pair of means (Manganese)

p	0.1	0.05	0.01	0.001
LSD	.031	.037	.049	.064

cont/

Table AP8 (cont.)

Tofieldietalia

Replicate No.	Zinc (mg/g.d.wt) Metalliferous uncovered	covered	Non-metalliferous uncovered	covered	Cadmium (mg/g.d.wt) Metalliferous uncovered	covered	Non-metalliferous uncovered	covered
1	.138	.178	.073	.065	.0020	.0025	.0010	.0010
2	.139	.144	.076	.077	.0013	.0020	.0010	.0010
3	.127	.165	.076	.069	.0019	.0016	.0009	.0007
4	.143	.138	.086	.079	.0018	.0020	.0014	.0010
5	.155	.165	.080	.057	.0023	.0015	.0012	.0008
6	.138	.129	.090	.056	.0021	.0020	.0014	.0006
7	.135	.126	.070	.051	.0029	.0011	.0011	.0009
8	.142	.129	.081	.076	.0020	.0018	.0008	.0013
9	.141	.163	.063	.058	.0016	.0016	.0011	.0008
10	.158	.150	.068	.081	.0020	.0021	.0008	.0010
11	.127	.128	.060	.059	.0015	.0010	.0007	.0009
12	.156	.140	.074	.071	.0025	.0020	.0010	.0012
$\bar{x}$	.142	.146	.075	.067	.0020	.0018	.0010	.0009

LSD for any pair of means (Zinc)

p	0.1	0.05	0.01	0.001
LSD	.008	.010	.014	.018

LSD for any pair of means (Cadmium)

p	0.1	0.05	0.01	0.001
LSD	.0002	.0003	.0004	.0005

cont/

Table AP8 (cont.)

Tofieldietalia

Replicate No.	Lead (mg/g.d.wt) Metalliferous uncovered	covered	Non-metalliferous uncovered	covered	Phosphorus (mg/g.d.wt) Metalliferous uncovered	covered	Non-metalliferous uncovered	covered
1	.0115	.0300	.0100	.0080	.625	.705	.583	.648
2	.0170	.0165	.0105	.0160	.648	.805	.515	.560
3	.0140	.0175	.0025	.0050	.650	.570	.623	.580
4	.0160	.0150	.0115	.0090	.600	.665	.545	.590
5	.0140	.0205	.0065	.0065	.598	.555	.663	.545
6	.0105	.0135	.0095	.0180	.678	.648	.530	.480
7	.0145	.0140	.0165	.0070	.718	.620	.650	.570
8	.0170	.0125	.0080	.0150	.710	.620	.583	.500
9	.0110	.0160	.0085	.0035	.630	.580	.650	.608
10	.0160	.0145	.0065	.0090	.675	.713	.563	.628
11	.0140	.0165	.0065	.0100	.685	.620	.740	.608
12	.0285	.0170	.0075	.0260	.660	.690	.605	.580
$\bar{x}$	.0153	.0170	.0087	.0111	.656	.649	.604	.575

LSD for any pair of means (Lead)

p	0.1	0.05	0.01	0.001
LSD	.0034	.0040	.0054	.0070

LSD for any pair of means (Phosphorus)

p	0.1	0.05	0.01	0.001
LSD	.039	.047	.063	.082

cont/

Seslerio-Mesobromion

Replicate No.	Magnesium (mg/g.d.wt) Metalliferous uncovered	covered	Non-metalliferous uncovered	covered	Aluminium (mg/g.d.wt) Metalliferous uncovered	covered	Non-metalliferous uncovered	covered
1	1.090	.465	.465	.630	.144	.176	.103	.051
2	.879	1.125	.788	1.015	.151	.101	.048	.052
3	1.260	.795	.890	.875	.230	.179	.089	.073
4	.771	.645	.480	.580	.139	.098	.054	.061
5	.850	1.263	.750	.938	.159	.085	.040	.033
6	1.040	.745	.840	.810	.293	.184	.106	.084
7	.713	.790	.505	.765	.125	.107	.063	.079
8	.888	1.275	.917	1.200	.119	.068	.055	.076
9	1.355	.805	.935	.665	.270	.195	.157	.055
10	.410	.474	.560	.680	.117	.080	.040	.093
11	.739	1.325	.802	1.410	.104	.185	.034	.059
12	1.060	.950	1.070	.725	.247	.199	.119	.049
13	.696	.505	.540	.645	.165	.084	.066	.050
14	.963	1.125	.700	1.213	.118	.053	.043	.030
15	1.360	.725	1.025	1.005	.184	.100	.123	.050
16	.970	.620	.520	.620	.080	.119	.060	.041
17	.800	1.338	.763	1.125	.108	.070	.048	.059
18	1.090	.690	1.125	.960	.310	.105	.135	.054
$\bar{x}$	.942	.870	.760	.881	.170	.122	.077	.058

LSD for any pair of means (Magnesium)

p	0.1	0.05	0.01	0.001
LSD	.140	.167	.222	.289

LSD for any pair of means (Aluminium)

p	0.1	0.05	0.01	0.001
LSD	.027	.032	.042	.055

cont/

Table AP8 (cont.)

Seslerio-Mesobromion

Replicate No.	Potassium (mg/g.d.wt) Metalliferous uncovered	Metalliferous covered	Non-metalliferous uncovered	Non-metalliferous covered	Calcium (mg/g.d.wt) Metalliferous uncovered	Metalliferous covered	Non-metalliferous uncovered	Non-metalliferous covered
1	12.90	12.95	8.80	10.90	3.21	3.74	2.51	3.26
2	12.56	11.13	16.00	13.69	6.58	7.33	4.90	5.71
3	12.60	10.05	13.10	11.70	5.92	5.12	6.43	7.73
4	13.07	13.50	14.25	14.50	3.21	4.32	2.40	3.83
5	16.38	13.06	15.75	13.03	7.26	7.45	5.21	6.65
6	11.30	12.25	11.25	12.15	6.57	6.77	6.48	7.13
7	13.45	12.25	12.30	14.45	3.69	4.46	2.94	4.17
8	16.38	11.69	15.95	13.75	6.56	8.78	6.07	6.26
9	12.80	8.95	12.00	11.60	8.22	5.17	6.43	4.54
10	13.85	11.32	14.50	12.20	3.73	3.55	2.86	4.83
11	15.18	12.75	10.31	14.20	6.59	8.13	5.33	6.33
12	13.00	11.40	13.50	11.65	7.32	6.67	8.43	5.68
13	12.70	9.80	11.45	11.60	4.39	3.98	2.65	3.92
14	15.25	11.60	17.25	14.00	7.91	7.31	5.95	6.59
15	13.35	9.25	13.15	12.00	7.72	6.32	7.03	6.03
16	12.35	12.00	12.75	13.10	2.98	4.06	2.91	4.12
17	13.92	11.95	17.75	14.75	5.90	7.80	4.66	8.05
18	11.20	11.10	14.15	13.15	6.22	6.27	7.53	5.53
$\bar{x}$	13.46	11.50	13.57	12.91	5.78	5.96	4.98	5.58

Potassium: LSD for any pair of means

p	0.1	0.05	0.01	0.001
LSD	.93	1.11	1.47	1.91

Calcium: LSD for any pair of means

p	0.1	0.05	0.01	0.001
LSD	.94	1.13	1.50	1.95

Table AP8 (cont.)

Seslerio-Mesobromion

Replicate No.	Iron (mg/g.d.wt) Metalliferous uncovered	covered	Non-metalliferous uncovered	covered	Manganese (mg/g.d.wt) Metalliferous uncovered	covered	Non-metalliferous uncovered	covered
1	.315	.430	.223	.138	.155	.089	.088	.143
2	.345	.563	.094	.198	.250	.185	.276	.275
3	.420	.310	.188	.193	.096	.055	.134	.109
4	.536	.225	.133	.188	.154	.059	.114	.146
5	.475	.388	.088	.075	.303	.203	.243	.260
6	.485	.355	.253	.213	.115	.055	.125	.124
7	.751	.235	.168	.473	.171	.064	.103	.160
8	1.488	.313	.098	.156	.326	.246	.200	.205
9	.410	.405	.338	.148	.122	.059	.115	.092
10	.843	.597	.103	.288	.146	.083	.094	.206
11	1.307	.600	.067	.080	.259	.371	.220	.333
12	.400	.370	.298	.128	.098	.068	.109	.109
13	1.349	.190	.178	.138	.164	.056	.120	.112
14	.425	.138	.106	.069	.303	.186	.289	.220
15	.320	.240	.313	.148	.110	.056	.094	.078
16	.315	.240	.143	.118	.115	.062	.119	.137
17	.348	.188	.106	.106	.167	.271	.223	.279
18	.580	.235	.338	.183	.130	.058	.108	.086
$\bar{x}$	.617	.335	.180	.169	.177	.124	.154	.171

LSD for any pair of means (Iron)

p	0.1	0.05	0.01	0.001
LSD	.119	.142	.188	.245

LSD for any pair of means (Manganese)

p	0.1	0.05	0.01	0.001
LSD	.044	.053	.070	.091

cont/

Table AP8 (cont.)

Seslerio-Mesobromion

Replicate No.	Zinc (mg/g.d.wt) Metalliferous uncovered	covered	Non-metalliferous uncovered	covered	Cadmium (mg/g.d.wt) Metalliferous uncovered	covered	Non-metalliferous uncovered	covered
1	.070	.056	.049	.045	.0015	.0006	.0005	.0006
2	.181	.144	.104	.088	.0025	.0020	.0031	.0021
3	.106	.058	.065	.069	.0023	.0004	.0010	.0011
4	.117	.069	.036	.042	.0024	.0009	.0006	.0005
5	.208	.126	.095	.089	.0025	.0015	.0015	.0015
6	.143	.082	.072	.067	.0023	.0008	.0010	.0010
7	.086	.074	.043	.059	.0011	.0012	.0003	.0004
8	.148	.121	.077	.084	.0026	.0014	.0021	.0016
9	.088	.064	.071	.062	.0013	.0010	.0010	.0008
10	.100	.046	.043	.056	.0011	.0014	.0003	.0008
11	.124	.144	.090	.088	.0020	.0019	.0019	.0018
12	.090	.063	.070	.064	.0013	.0008	.0015	.0009
13	.102	.057	.063	.035	.0016	.0008	.0004	.0005
14	.153	.098	.119	.085	.0025	.0011	.0021	.0020
15	.102	.071	.061	.039	.0020	.0006	.0010	.0011
16	.077	.069	.036	.044	.0010	.0006	.0006	.0006
17	.156	.123	.099	.103	.0021	.0013	.0026	.0020
18	.173	.084	.066	.049	.0028	.0006	.0009	.0011
$\bar{X}$	.124	.086	.070	.065	.0019	.0011	.0012	.0011

Zinc: LSD for any pair of means

p	0.1	0.05	0.01	0.001
LSD	.017	.020	.026	.034

Cadmium: LSD for any pair of means

p	0.1	0.05	0.01	0.001
LSD	.0003	.0004	.0005	.0007

cont/

Table AP8 (cont.)

Seslerio-Mesobromion

Replicate No.	Lead (mg/g.d.wt) Metalliferous uncovered	Metalliferous covered	Non-metalliferous uncovered	Non-metalliferous covered	Phosphorus (mg/g.d.wt) Metalliferous uncovered	Metalliferous covered	Non-metalliferous uncovered	Non-metalliferous covered
1	.0160	.0330	.0195	.0110	.705	.560	.555	.525
2	.0267	.0750	.0150	.0103	.721	.825	1.011	.678
3	.0275	.0475	.0220	.0125	.690	.558	.737	.613
4	.0160	.0255	.0105	.0155	.729	.565	.780	.625
5	.0175	.0400	.0163	.0013	.928	.954	.946	.773
6	.0340	.0550	.0230	.0155	.674	.640	.711	.584
7	.0184	.0255	.0140	.0140	.470	.493	.645	.645
8	.0213	.0513	.0105	.0238	.895	.875	.790	.805
9	.0310	.0540	.0325	.0115	.682	.451	.771	.674
10	.0146	.0168	.0075	.0165	.869	.490	.790	.645
11	.0185	.0575	.0153	.0013	.803	1.089	.772	.912
12	.0285	.0625	.0345	.0080	.755	.521	.800	.648
13	.0165	.0225	.0175	.0110	.827	.438	.705	.545
14	.0322	.0413	.0150	.0088	.825	.773	.991	.954
15	.0240	.0425	.0300	.0125	.769	.498	.682	.708
16	.0090	.0240	.0120	.0105	.708	.480	.678	.405
17	.0261	.0375	.0188	.0113	.827	.915	1.044	1.089
18	.0360	.0395	.0350	.0110	.674	.590	.774	.766
$\bar{X}$	.0230	.0417	.0194	.0115	.753	.651	.788	.700

LSD for any pair of means (Lead)

p	0.1	0.05	0.01	0.001
LSD	.0056	.0066	.0088	.0114

LSD for any pair of means (Phosphorus)

p	0.1	0.05	0.01	0.001
LSD	.086	.103	.137	.177

Table AP.9 Weights of individual plants of

C. panicea collected in the field at Teesdale 1973

	March	April	May	June	July	Aug.	Sept.
1	.0310	.0476	.0641	.0210	.0758	.0532	.0230
2	.0331	.0328	.0324	.0173	.0718	.0548	.0650
3	.0852	.0559	.0266	.0152	.0755	.1033	.0540
4	.0453	.0477	.0500	.0349	.0651	.0902	.0440
5	.0286	.0437	.0587	.0220	.0545	.0615	.0400
6	.0181	.0404	.0626	.0128	.0886	.0551	.0320
7	.0240	.0364	.0487	.0366	.0254	.0828	.0470
8	.0520	.0505	.0489	.0155	.0217	.0649	.0810
9	.0263	.0191	.0118	.0246	.0254	.0726	.0550
10	.0349	.0302	.0254	.0112	.0537	.1020	.0550
11	.0229	.0303	.0376	.0245	.0093	.0367	.0720
12	.0529	.0533	.0536	.0330	.0252	.0548	.0790
13	.0203	.0324	.0445	.0381	.0723	.0417	.0660
14	.0403	.0520	.0636	.0496	.0806	.0707	.0590
15	.0482	.0500	.0517	.0268	.0671	.1166	.0610
16	.0327	.0588	.0848	.0465	.1084	.0648	.0540
17	.0316	.0428	.0539	.0335	.0531	.0425	.0590
18	.0616	.0648	.0679	.0708	.0509	.0400	.0440
19	.0282	.0530	.0778	.0423	.0946	.0362	.0680
20			.0307	.0422	.0764	.0862	.0540
21			.0842	.0125	.0980	.0701	.0950
22			.0760	.0483	.0906	.0535	.0500
23			.0175	.0471	.0390	.0573	.0250
24			.1104	.0561	.0272	.0269	.0840
25			.0300	.0561	.0329	.0825	.0460
26			.0586	.0409	.0360	.1002	.0520
27			.0784	.0283	.0245	.0794	.0600
28			.0499	.0197	.0449	.0339	.0520
29			.0324	.0455	.0299	.1006	.0530
30			.0422	.0202	.0643	.0731	
31				.0626	.0372	.0460	
32				.0333	.0478	.0570	
33				.0276	.0357	.0775	
34				.0610	.0284	.0375	
35				.0271	.0225	.0818	

cont/

Table AP.9 (cont.)

36	.0174	.0400	.0712
37	.0340	.0130	
38	.0511	.0300	
39	.0603	.0532	
40	.0982		
41	.0867		
42	.0171		
43	.0405		
44	.0425		
45	.0380		
46	.0609		
47	.0780		
48	.0265		
49	.0148		

cont/

C. panicea at Sunbiggin

	March	April	May	June	July	Aug.	Sept.
1	.0925	.0191	.2906	.0502	.1536	.1018	.0270
2	.0826	.0776	.0726	.0833	.1160	.1455	.0350
3	.0900	.0874	.0848	.0720	.0530	.0452	.0770
4	.0875	.1081	.1286	.0558	.0809	.0529	.1120
5	.2601	.1803	.1003	.1164	.1269	.0915	.0830
6	.1432	.1148	.0864	.0452	.0658	.1186	.1060
7	.1482	.0898	.0314	.0284	.0226	.0392	.0350
8	.0497	.0871	.1244	.0674	.0388	.0914	.1050
9	.1066	.1458	.1850	.0357	.0337	.0856	.0420
10	.1038	.0689	.0340	.0465	.0216	.1600	.0820
11	.0669	.0427	.0183	.0813	.0321	.0937	.0190
12	.0249	.0276	.0303	.0813	.0304	.0532	.0840
13	.0738	.1030	.1322	.0768	.0200	.0561	.0450
14	.1048	.1549	.2049	.0613	.0695	.0922	.1060
15	.0937	.0719	.0499	.1108	.0934	.2587	.0580
16	.0332	.0377	.0421	.0818	.0587	.1284	.0370
17	.0790	.2236	.3681	.0608	.0655	.1611	.1050
18	.0994	.1489	.1983	.0611	.1961	.1745	.0670
19	.0822	.0890	.0957	.1198	.1489	.0855	.0390
20	.1950	.1623	.1296	.0291	.1396	.1293	.0450
21	.2119	.2187	.2255	.1427	.0750	.0979	.1280
22	.0298	.0598	.0898	.0600	.0841	.1414	.0950
23		.0790	.0655	.0994	.1030	.0392	.1210
24		.2583	.4340	.0585	.0576	.1880	.0410
25			.3726	.0475	.0665	.0537	.0750
26			.0676	.1044	.1357	.0568	.1120
27			.0995	.0885	.0382	.1500	.0620
28			.0304	.0695		.1184	.1180
29			.0609	.0947		.1149	.1250
30			.0718	.0493		.0346	.0820
31			.0760	.1049		.0681	
32			.1763	.0520		.0615	
33			.0645	.0377			
34			.1052	.0650			
35			.1330	.0950			
36			.2723	.0444			

cont/

Table AP.9 (cont.)

37	.0451
38	.0382
39	.0465
40	.0847
41	.1144
42	.0666
43	.0411
44	.1220
45	.0620

cont/

C. lepidocarpa at Teesdale

	March	April	May	June	July	Aug	Sept
1	.0780	.0716	.0652	.0513	.0752	.0213	.0425
2	.0785	.0654	.0522	.0711	.0879	.0240	.0335
3	.0628	.0626	.0623	.0234	.0579	.1540	.0800
4	.0500	.0614	.0728	.0427	.0581	.0652	.0510
5	.0818	.0888	.0957	.1066	.0888	.0958	.0530
6	.0476	.0816	.1156	.0402	.0804	.1995	.0310
7	.0489	.1070	.1650	.0292	.0613	.0283	.0590
8	.0348	.0520	.0691	.0435	.0358	.0995	.1070
9	.0753	.1049	.1344	.0383	.0895	.0714	.0480
10	.0434	.0436	.0437	.0737	.0800	.0730	.0260
11	.0677	.0728	.0778	.0956	.0751	.1910	.0270
12	.0717	.1498	.2279	.0167	.1051	.1972	.0840
13	.0542	.0633	.0723	.0649	.0663	.0786	.0580
14	.0323	.0664	.1004	.0451	.0891	.1243	.0640
15	.0684	.0954	.1224	.0441	.0847	.0380	.0980
16	.1161	.1023	.0884	.0438	.0669	.0927	.0730
17	.0275	.0550	.0824	.0814	.1712	.0591	.0590
18	.0475	.0521	.0567	.1118	.0179	.0674	.0880
19	.0785	.0823	.0861	.0467	.1379	.0219	.0710
20	.0365	.0604	.0842	.0905	.1032	.0411	.0660
21	.0375	.1004	.1633	.0492	.1091	.0738	.0930
22	.0725	.0978	.1230	.0536	.0846	.0661	.0540
23	.0608	.0554	.0499	.0552	.0934	.1066	.0150
24	.0418	.0635	.0852	.0352	.1083	.0701	.0320
25	.0759	.0744	.0729	.0749	.0444	.0683	.0730
26	.0337	.0522	.0706	.1043	.1176	.1013	.0700
27	.0622	.1039	.1455	.0735	.1320	.0889	.0200
28	.0875	.0607	.0339	.0318	.0948	.0962	.0790
29	.0264	.0391	.0517	.1011	.1124	.0628	.1040
30	.0699	.0621	.0542	.0386	.0794	.0643	.0500
31	.0389	.0976	.1562	.1263	.0983	.0703	.1270
32			.0234	.0489	.0746	.0603	.0550
33			.1052	.0403	.0664	.0516	.0890

cont/

Table AP.9 (cont.)

34	.1451	.1256	.0239	.1119	.0750
35		.0765	.0747	.0845	.0270
36		.1138	.1673	.1316	.0680
37		.0338	.0844	.1091	.0280
38		.0965	.0388	.0494	.0390
39		.0504		.0250	.0590
40		.0824		.0458	
41		.1502		.0620	
42				.0216	
43				.0879	
44				.1137	
45				.0235	
46				.0435	
47				.0697	
48				.0564	
49				.0400	
50				.0764	
51				.0517	
52				.0473	
53				.0567	
54				.0542	

cont/

Table AP.9 (cont.)

C. Iepidocarpa at Sunbiggin

	March	April	May	June	July	Aug	Sept
1	.0846	.1000	.1154	.0781	.0900	.0285	.0460
2	.0466	.0865	.1263	.1010	.1487	.1695	.1190
3	.0400	.1007	.1614	.0565	.1626	.1392	.0680
4	.0852	.0923	.0993	.0900	.0998	.1299	.0250
5	.0847	.1064	.1280	.2448	.2799	.0869	.2120
6	.0453	.0617	.0781	.2126	.0482	.1740	.0450
7	.0774	.1673	.2572	.0965	.1975	.2046	.0900
8	.0665	.1093	.1521	.1209	.1497	.0873	.1360
9	.0665	.0961	.1256	.0754	.0873	.1214	.0420
10	.0884	.1225	.1565	.0896	.0495	.1040	.1380
11	.0410	.0674	.0938	.0916	.0799	.1083	.0970
12	.1088	.1618	.2148	.0995	.1116	.1523	.0820
13	.0852	.1738	.2624	.0495	.1184	.1229	.0600
14	.1150	.1940	.2729	.1114	.0721	.0407	.0400
15	.0900	.0764	.0628	.1803	.0725	.0887	.1030
16	.1153	.1373	.1593	.0583	.0414	.0907	.1630
17	.0992	.1041	.1089	.0629	.0321	.1514	.1940
18	.1437	.1001	.0564	.1294	.0895	.0675	.1120
19	.1356	.1239	.1121	.1241	.0856	.0865	.0780
20	.1085	.1443	.1800	.1376	.0824	.0981	.0770
21	.0862	.1045	.1228	.1495	.2177	.0493	.0350
22	.0863	.0746	.0629	.1267	.0994	.0852	.0720
23	.0744	.0987	.1229	.1454	.0594	.0836	.1250
24	.0663	.0936	.1208	.0936	.1232	.1726	.1840
25	.0382	.1296	.2209	.0645	.2511	.1255	.2390
26	.0682	.1014	.1346	.0659	.0648	.1202	.1070
27	.0343	.1253	.2163	.0698	.0660	.1887	.2050
28			.1958	.0625	.1909	.0950	.1500
29			.1368	.0740	.0403	.0935	.0500
30			.1715	.0453	.0389	.2055	.0400

cont/

Table AP.9 (cont.)

31	.1228	.0811	.1630	.1170	.1190
32	.0526	.0664		.1457	.1140
33	.0989	.1916		.0685	.1890
34	.0606			.1123	.1140
35	.0615			.1398	.1000
36	.0801			.2671	.0720
37	.0643			.1626	.0420
38	.0846			.0714	.2900
39	.1326			.0775	.2820
40	.2180			.1904	.1410
41	.0882			.0740	.2720
42	.0708			.1059	
43	.1614			.1555	
44	.0778			.0429	
45				.1100	
46				.1015	
47				.1022	
48				.1730	
49				.0874	
50				.1969	

Table AP.9 (cont.)

S. caerulea at Teesdale

	March	April	May	June	July	Aug	Sept
1	.0054	.0069	.0083	.0500	.0318	.0195	.0400
2	.0156	.0204	.0251	.0174	.0337	.0155	.0170
3	.0143	.0154	.0164	.0136	.0254	.0139	.0270
4	.0318	.0281	.0244	.0398	.0521	.0376	.0240
5	.0687	.0481	.0273	.0537	.0308	.0201	.0230
6	.0090	.0067	.0044	.0226	.0360	.0249	.0170
7	.0330	.0340	.0348	.0280	.0333	.0142	.0410
8	.0089	.0103	.0116	.0216	.0505	.0109	.0110
9	.0091	.0218	.0345	.0261	.0465	.0424	.0100
10	.0185	.0316	.0446	.0287	.0633	.0188	.0200
11	.0182	.0205	.0227	.0246	.0472	.0379	.0120
12	.0161	.0111	.0060	.0085	.0319	.0313	.0240
13	.0234	.0237	.0239	.0336	.0146	.0157	.0240
14	.0139	.0142	.0144	.0268	.0172	.0243	.0300
15	.0059	.0264	.0468	.0174	.0365	.0405	.0430
16	.0186	.0217	.0247	.0529	.0117	.0197	.0220
17	.0157	.0158	.0158	.0231	.0868	.0149	.0200
18	.0203	.0205	.0203	.0116	.0327	.0597	.0480
19	.0161	.0336	.0511	.0245	.0600	.0212	.0290
20	.0137	.0118	.0099	.0155	.0234	.0200	.0240
21	.0212	.0336	.0460	.0235	.0364	.0369	.0270
22	.0245	.0289	.0332	.0298	.0294	.0512	.0240
23	.0088	.0262	.0455	.0570	.0655	.0269	.0550
24	.0223	.0236	.0328	.0318	.0453	.0239	.0290
25	.0088	.0330	.0170	.0113	.0600	.0516	.0500
26	.0108	.0264	.0419	.0170	.0344	.0454	.0290
27		.0073	.0091	.0274	.0167	.0182	.0260
28		.0183	.0209	.0251	.0326	.0257	.0210
29		.0175	.0206	.0235	.0641	.0595	.0690
30		.0203	.0087	.0406	.0236	.0519	.0510
31		.0457	.0226	.0332	.0448	.0418	.0400
32		.0084	.0077	.0289	.0509	.0143	.0280
33		.0298	.0266	.0237	.0326	.0220	.0160
34		.0203	.0317	.0051	.0640	.0254	.0220
35		.0239	.0386	.0422	.0425	.0182	.0110
36		.0158	.0130	.0265	.0186	.0281	.0450

cont/

Table AP.9 (cont.)

37	.0135	.0347	.0372	.0391	.0210
38	.0317	.0206	.0388	.0330	.0420
39	.0238	.0132	.0545	.0173	.0280
40	.0665	.0685	.0500	.0136	.0110
41	.0241	.0242	.0382	.0514	.0200
42	.0188	.0173	.0262	.0222	
43	.0164	.0234	.0240	.0195	
44	.0298	.0255	.0224	.0229	
45	.0201	.0285	.0410	.0292	
46	.0261	.0347	.0300	.0333	
47	.0578	.0275	.0320	.0521	
48	.0202	.0311	.0628	.0300	
49	.0347	.0516	.0390	.0335	
50	.0351	.0401	.0520	.0753	
51	.0188	.0311	.0237	.0353	
52	.0487	.0375	.0414	.0232	
53	.0365	.0171	.0342	.0417	
54	.0478	.0203	.0180	.0680	
55	.0244	.0241	.0148	.0335	
56	.0419	.0248	.0288	.0245	
57	.0519	.0432	.0425	.0154	
58	.0154	.0131	.0367		
59	.0140	.0417			
60	.0149	.0603			
61	.0250	.0125			
62	.0260	.0373			
63	.0143	.0315			
64	.0191	.0236			
65	.0213	.0134			
66	.0243	.0461			
67	.0310	.0489			
68	.0194	.0476			
69	.0077	.0530			
70	.0199	.0338			
71	.0276	.0216			
72	.0183	.0151			
73	.0101	.0177			

cont/

Table AP.9 (cont.)

74	.0138	.0238
75	.0127	.0471
76	.0227	.0151
77	.0263	.0577
78	.0571	.0176
79	.0181	.0464
80	.0130	.0294
81	.0188	.0366
82	.0458	.0203
83	.0125	.0211
84	.0212	.0087
85	.0093	.0326
86	.0306	.0097
87	.0280	.0351
88	.0212	.0275
89	.0188	.0605
90	.0142	.0130
91	.0282	.0377
92	.0163	.0430
93	.0234	.0417
94	.0246	.0364
95	.0181	.0569

cont/

Table AP.9 (cont.)

S. caerulea at Sunbiggin

	March	April	May	June	July	Aug.	Sept.
1	.0336	.0418	.0499	.0246	.0683	.0717	.0260
2	.0130	.0154	.0178	.0164	.0582	.0378	.0190
3	.0169	.0148	.0127	.0330	.0448	.0316	.0440
4	.0098	.0151	.0202	.0161	.0362	.0778	.0310
5	.0160	.0174	.0187	.0373	.0122	.0533	.0400
6	.0125	.0212	.0299	.0315	.0352	.0304	.0340
7	.0084	.0113	.0142	.0415	.0381	.0416	.0300
8	.0382	.0256	.0129	.0500	.0488	.0523	.0530
9	.0350	.0208	.0064	.0721	.1653	.0455	.0320
10	.0227	.0152	.0076	.0301	.0428	.0359	.0200
11	.0376	.0325	.0274	.0218	.0528	.0384	.0190
12	.0640	.0399	.0158	.0318	.0781	.0308	.0300
13	.0211	.0150	.0089	.0241	.0222	.0936	.0300
14	.0115	.0124	.0132	.0317	.0390	.0662	.0360
15	.0264	.0288	.0311	.0202	.0405	.1065	.0410
16	.0395	.0273	.0151	.0402	.0514	.0784	.0200
17	.0302	.0256	.0208	.0390	.0297	.1043	.0280
18	.0743	.0549	.0354	.0416	.0465	.0224	.0230
19	.0328	.0289	.0250	.0716	.0445	.0239	.0260
20	.0404	.0323	.0241	.0251	.1118	.0256	.0270
21	.0440	.0362	.0279	.0191	.0455	.0376	.0400
22	.0559	.0395	.0231	.0108	.0416	.0208	.0440
23			.0206	.0519	.0369	.0610	.0950
24			.0097	.0557	.0420	.0482	.0980
25			.0224	.0417	.0562	.0521	.0310
26			.0239	.0215	.0646	.0476	.0320
27			.0321	.0585	.0669	.0430	.0210
28			.0247	.0333	.0191	.0287	.0320
29			.0235	.0277	.0532	.0551	.0240
30			.0215	.0429	.0603	.0436	.0320
31			.0159	.0278	.0338	.0680	.0250
32			.0172	.0289	.0670	.0381	
33			.0164	.0369	.0339	.0592	
34			.0314	.0319	.0634	.0294	
35			.0153	.0276	.0400	.0275	
36			.0181	.0240	.0729	.0327	
37			.0386	.0430	.0304	.0852	

cont/

Table AP.9 (cont.)

38	.0130	.0190	.0345	.0738
39		.0329	.0386	.0411
40		.0336	.0269	.0268
41		.0308	.0294	.0788
42		.0452	.0831	.0894
43		.0523	.0420	.0914
44		.0492	.0465	.0610
45		.0427	.0712	.0299
46		.0122	.0403	.0400
47		.0161	.0312	.0743
48		.0284	.0380	.1330
49		.0382	.0349	.0614
50		.0286	.0159	.0562
51		.0527	.0372	.0900
52		.0506	.0359	.0475
53		.0364	.0213	.0378
54		.0266	.0212	.0360
55		.0140	.0394	.0613
56		.0181	.0287	.0263
57		.0167	.0287	.0400
58		.0195	.0363	.0419
59		.0196	.0256	.0764
60		.0170	.0288	.0596
61		.0351	.0254	.0468
62		.0163	.0315	.0570
63		.0226	.0397	.0540
64		.0137	.0382	.0478
65		.0299	.0485	.0648
66		.0240	.0410	.0442
67		.0326	.0237	.0363
68		.0482	.0664	.0248
69		.0389	.0548	.0300
70		.0377	.0247	
71		.0301	.0521	
72		.0251	.0427	
73		.0470		
74		.0331		
75		.0384		
76		.0244		

cont/

Table AP10 Growth data for the species grown in pots at Durham

l.l./t.	= live leaf length/tiller
$\sum$	= total live leaf length
t.n.	= tiller no.
P.	= pot no.
T	= Teesdale *Tofieldietalia* soil
S	= Sunbiggin *Tofieldietalia* soil

cont/

Table AP10 (cont.) C. lepidocarpa

	2.2.73.	16.5.73.				1.6.73.				16.6.73.				2.7.73.				17.7.73.				25.8.73.			
	1.1./t.	1.1./t.				1.1./t.				1.1./t.				1.1./t.				1.1./t.				1.1./t.			
P \ tn	1	1	2	3	Σ	1	2	3	Σ	1	2	3	Σ	1	2	3	Σ	1	2	3	Σ	1	2	3	Σ
T1	21.0	37.5			37.5	42.0			42.0	37.0	11.5		48.5	31.5	25.0		56.5	21.5	33.0		54.5	7.5	50.0		57.5
T3	21.5	27.0			27.0	31.5			31.5	31.0	12.0		43.0	29.0	30.0		59.0	23.0	40.5		63.5	6.5	60.5		67.0
T5	19.5	44.5	11.5		56.0	45.0	19.0		64.0	35.0	31.5		66.5	29.0	47.0		76.0	25.5	65.0		90.5	11.5	79.5	3.0	94.0
T7	26.0	36.0			36.0	38.5	4.0		42.5	37.5	16.5		54.0	30.0	32.0		63.0	14.0	45.0		59.0	6.0	54.0		60.0
T9	31.5	49.5			49.5	58.5	3.0	3.0	64.5	53.5	10.0	9.5	73.0	40.0	20.5	17.0	77.5	31.0	29.5	24.0	84.5	7.0	43.0	25.0	75.0
T12	24.0	43.0			43.0	46.0	5.5		51.5	37.0	14.5		51.5	26.5	26.5		53.9	16.5	37.5		54.0	8.0	47.5		55.5
T14	34.0	41.0	2.5	6.0	49.5	49.5	12.0	-	61.5	37.0	24.5	-	61.5	32.0	38.5	-	70.5	37.0	58.5	-	95.5	20.0	61.0	9.5	90.5
T16	23.5	44.0			44.0	49.5			49.5	43.5			43.5	38.5	14.5		53.0	20.0	24.0		44.0	6.5	28.0		34.5
T18	25.5	40.5	3.0		43.5	43.0	9.0		52.0	34.0	15.0		49.0	29.0	22.0		51.0	14.0	30.0		44.0	5.5	32.5		38.0
T20	13.0	9.5			9.5	10.5			10.5	9.5	1.5		11.0	9.5	9.0		18.5	9.5	17.5		27.0	3.5	25.5		29.0
T21	31.5	23.0			23.0	34.5	3.0		37.5	35.0	9.5		44.5	25.0	18.5		43.5	25.0	29.0		54.0	10.0	34.5		44.5
T23	29.5	63.0	11.5	5.5	80.0	65.0	20.0		85.0	51.0	30.0	3.0	84.0	37.0	35.5		72.5	24.5	64.5		89.0	10.5	67.5		78.0
T25	25.5	55.0			55.0	51.0	4.0	8.5	63.5	39.0	19.5	10.5	69.0	23.0	30.5	12.5	66.0	17.0	44.0	13.0	74.0	8.0	58.0	11.5	77.5
T27	32.0	51.0			51.0	53.0	5.0		58.0	38.0	17.0		55.0	30.5	29.0		59.5	17.0	36.0		53.0	10.0	48.5		58.5
T29	22.5	10.5			10.5	14.5			14.5	25.5	2.5		28.0	24.5	13.0		37.5	23.5	26.0		49.5	14.5	40.0		54.5
$\bar{x}$	25.36				41.00				48.53				52.13				57.06				62.40				60.93
S2	17.0	37.0			37.0	28.0			28.0	32.5			32.5	16.5			16.5	12.0			12.0	4.0			4.0
S4	23.0	31.0			31.0	43.0			43.0	49.0			49.0	57.0			57.0	60.5			60.5	54.0			54.0
S6	27.5	28.0	6.5		34.5	35.5	10.5		46.0	31.5	22.5		54.0	17.5	35.0		52.5	9.0	42.5		51.5	-	55.0		55.0
S8	15.5	30.0			30.0	34.0			34.0	29.0	2.0		31.0	23.5	6.0		29.5	14.0	12.5		26.5	3.5	16.5		20.0
S10	20.0	40.0	5.5		45.5	39.5	8.5		48.0	24.5	16.5		41.0	15.0	24.5		39.5	6.0	29.5		35.5	2.0	28.0		30.0
S11	21.0	48.5			48.5	32.5			32.5	35.5	4.0		39.5	28.5	13.5		42.0	18.0	21.0		39.0	3.5	34.0		37.5
S13	29.0	49.0	1.5		50.5	54.5	2.5	3.5	60.5	39.5	11.5	5.5	56.5	25.5	19.5	6.0	51.0	11.0	23.0	5.0	39.0	4.0	31.0	-	35.0
S15	26.5	37.5			37.5	46.0			46.0	38.0	7.0	1.5	46.5	32.5	18.0	-	50.5	24.0	25.0	-	49.0	8.5	32.5	-	41.0
S17	31.0	70.0	13.5		83.5	66.0	25.5		91.5	43.0	36.5		79.5	27.0	47.0		74.0	7.5	59.0		66.5	-	51.5		51.5
S19	24.5	50.5	1.0		51.5	51.0	4.5		55.5	34.5	10.0		44.5	21.5	15.5		37.0	12.0	23.0		35.0	1.5	25.0		26.5
S22	28.0	51.0			51.0	48.0	6.5		54.5	42.0	15.0		57.0	23.0	24.0		47.0	13.0	30.5		43.5	3.0	35.5		38.5
S24	21.0	38.5	20.5		59.0	39.0	22.5		61.5	31.5	19.0		50.5	26.0	18.5		44.5	11.0	14.5		25.5	-	7.0		7.0
S26	15.0	35.0			35.0	28.5			28.5	22.0			22.0	11.5			11.5	7.0			7.0	2.0			2.0
S28	19.0	23.5			23.0	27.5			27.5	33.0			33.0	38.5			38.5	44.5			44.5	42.5			42.5
S30	14.0	34.5			34.5	30.5			30.5	24.0			24.0	19.0			19.0	10.5			10.5	3.5	2.0		5.5
$\bar{x}$	22.13				43.46				45.83				44.03				40.60				36.36				30.00

cont/

Table AP10 (cont.) C. Panicea

	2.2.73. l.l./t.	17.5.73. l.l./t.						2.6.73. l.l./t.					
P \ t.n.	1	1	2	3	4	5	Σ	1	2	3	4	5	Σ
T121	13.0	27.5	1.5				29.0	30.5	1.5				32.0
T123	17.0	25.5	2.0				27.5	34.0	5.0				39.0
T125	7.0	25.0	6.5				31.5	37.5	13.5	13.0			64.0
T127	8.0	20.5	6.5				27.0	20.5	12.0	6.5			39.0
T129	13.0	25.5	10.0	9.0			44.5	30.5	17.5	10.5			58.5
T132	8.0	16.5	11.5				28.0	22.5	16.5				39.0
T134	14.0	22.0					22.0	27.5	2.0				29.5
T136	13.0	20.5	6.5				27.0	17.5	12.5				30.0
T138	7.0	29.0	17.0				46.0	21.5	17.5				39.0
T140	3.0	26.5	12.0	6.5			45.0	28.5	19.5	6.5			54.5
T141	-	12.0	9.5				21.5	16.5	6.0				22.5
T143	12.0	40.0	15.5	4.5			60.0	47.5	20.0	17.5	9.0		94.0
T145	15.0	37.0	23.5	19.5	18.0	15.5	113.5	40.0	31.0	24.5	19.5	16.5	131.5
T147	7.0	21.5	10.5				32.0	18.5	13.0				31.5
T149	9.0	17.5	12.0				29.5	17.5	18.0				35.5
$\bar{x}$	10.42						38.93						49.3

S122	11.0	28.0	7.0				35.0	37.5	12.0				49.5
S124	1.0	6.0	9.5				15.5	3.5	15.0				18.5
S126	13.0	18.0	13.5				31.5	20.0	21.0				41.0
S128	7.0	16.5	14.5				31.0	17.5	23.5				41.0
S130	-	13.0	8.5	4.5			26.0	25.0	15.5	10.0			50.5
S131	10.0	11.0	5.5				16.5	12.5	11.5				24.0
S133	15.0	29.0					29.0	35.0					35.0
S135	18.0	27.5	14.0				41.5	31.5	18.0				49.5
S137	20.0	35.0	13.0	6.0			54.0	29.0	20.0	11.0			60.0
S139	14.0	23.0	8.5				31.5	16.0	14.5				30.5
S142	15.0	23.5	4.0	3.5			31.0	27.5	8.5	3.0			39.0
S144	8.0	21.5	4.5				26.0	21.0	5.0				26.0
S146	16.0	35.5	13.0				48.5	28.5	22.5				51.0
S148	4.0	19.5	3.5				23.0	28.5	14.5				43.0
S150	-	11.5	12.5				24.0	10.5	16.5				27.0
$\bar{x}$	11.69						30.93						39.03

cont/

25.8.73.
1.1./t.

5	6	7	Σ	1	2	3	4	5	6	7	8	Σ
			50.5	43.5		3.0						46.5
			74.0	67.0	18.5							85.5
			120.5	26.0	58.0	30.0	15.0					129.0
			37.0	-	34.5	6.0	3.0					43.5
			86.0	7.0	42.5	21.5	19.5					90.5
			58.0	13.0	56.0	4.5						73.5
			49.0	44.5	11.0							55.5
			35.0	-	41.0	5.0						46.0
			57.0	2.5	56.0							58.5
			113.0	14.5	59.5	35.5	19.0					128.5
			46.5	44.5	8.0							52.5
			145.0	11.5	60.0	52.5	24.0	2.5				150.5
18.0	13.0	3.0	215.0	8.5	61.0	49.5	35.5	26.5	23.5	10.0	3.5	218.0
			61.0	14.0	49.0							63.0
			43.5	5.0	46.0							51.0
			79.40									86.13
			59.0	16.0	31.5							47.5
			19.0	-	16.5							16.5
			40.5	2.0	27.0	9.0						38.0
			45.0	-	38.0							38.0
			69.5	9.5	38.0	14.5						62.0
			23.5	-	26.0							26.0
			35.0	31.5								31.5
			59.0	-	55.0							55.0
			54.5	-	14.5							54.0
			29.5	-	26.0							26.0
			47.0	20.5	28.5							49.0
			41.0	12.5	28.5							41.0
			40.5	-	38.0							38.0
			43.0	5.5	36.0							41.5
			29.5	-	26.0							26.0
			42.36									39.33

cont/

Table AP10 (cont.) Eriophorum latifolium

	2.2.73. l.l./t.	17.5.73. l.l./t.	2.6.73. l.l./t.			17.6.73. l.l./t.			2.7.73. l.l./t.				17.7.73. l.l./t.				25.8.73. l.l./t.			
P \ tn	1	1	1	2	Σ	1	2	Σ	1	2	3	Σ	1	2	3	Σ	1	2	3	Σ
T31		6.0	7.5			10.5		10.5	15.5	5.0	5.0	25.5	17.5	11.0	9.5	38.0	8.5	14.0	14.0	36.5
T33	18.0	12.0	20.0			22.5	3.5	26.0	24.0	9.0		33.0	21.5	11.0		32.5		11.5		11.5
T35	17.0	10.0	17.5			22.0		22.0	23.5	5.0		28.5	19.5	14.5		34.0		17.5		17.5
T37	22.0	16.5	22.5			34.0		34.0	46.0			46.0	53.0			53.0	53.0	3.0		56.0
T39	6.0	6.0	6.0			5.5		5.5	20.5			20.5	32.5			32.5	37.0			37.0
T42	12.0	3.5	3.0			2.0		2.0	3.0			3.0	3.0			3.0				
T44	10.0	5.5	9.5			15.5		15.5	24.0			24.0	28.0			28.0	31.5	1.5		33.0
T46	1.0	4.5	4.0			4.0		4.0	8.0			8.0	16.5			16.5	23.5			23.5
T48	18.0	6.0	8.0			5.5		5.5	10.0			10.0	17.0			17.0	38.5			38.5
T50	4.0	6.0	6.5			11.5		11.5	19.0			19.0	29.5			29.5	29.0			29.0
T51	13.0	10.0	11.0			15.0		15.0	28.0			28.0	20.5	7.5		28.0	27.0			27.0
T53	16.0	15.0	17.0			21.5	3.0	24.5	25.0	8.5		33.5	25.0	10.5		35.5	7.5	12.0		19.5
T55	21.0	16.0	12.0			27.0		27.0	38.0			38.0	47.5	11.0		58.5	48.0	19.5		67.5
T57	4.0	4.0	6.0			13.5		13.5	19.5			19.5	26.0			26.0	24.5			24.5
T59	13.0	5.0	3.5			7.5		7.5	17.5			17.5	23.5			23.5	32.0			32.0
x̄	12.50	8.40	10.26					14.93				23.60				30.36				32.35
S32	9.0	10.0	14.5	3.5	18.0	15.5	9.0	24.5	14.5	17.5		32.0	13.0	22.5		35.5	5.0	26.5		31.5
S34	7.0	5.0	7.0		7.0	10.0		10.0	18.5			18.5	22.0	3.5		25.5	18.0	14.0		32.0
S36	10.0	10.0	13.0		13.0	16.5		16.5	22.0			22.0	24.5			24.5	23.0			23.0
S38	12.0	13.5	19.0		19.0	23.5		23.5	20.0	1.0		21.0	18.5	6.0	2.0	26.5	6.5	11.5		18.0
S40	16.0	8.0	12.5		12.5	20.0		20.0	32.0			32.0	39.5			39.5	31.0			31.0
S41	17.0	16.5	22.5		22.5	32.0		32.0	45.5			45.5	50.5			50.5	48.0	4.5	3.0	55.5
S43	11.0	13.0	15.5		15.5	23.0		23.0	34.0			34.0	39.5			39.5	38.5			38.5
S45	15.0	17.0	24.5		24.5	29.5		29.5	36.0			36.0	35.5	4.0		39.5	32.0	10.0		42.0
S47	7.0	3.5	2.0		2.0	1.0		1.0	1.0			1.0								
S49	16.0	18.5	23.5		23.5	29.5		29.5	37.0			37.0	41.0			41.0	37.5	7.5		45.0
S52	11.0	9.5	7.5		7.5	12.5		12.5	23.0			23.0	30.0			30.0	33.0			33.0
S54	1.0	6.5	10.5		10.5	17.5		17.5	24.5			24.5	27.0			27.0	27.5			27.5
S56	23.0	28.0	28.5	2.5	31.0	33.0	15.5	48.5	14.5	27.5		42.0	27.5	40.5		68.0	4.5	55.0		59.5
S58	9.0	7.5	5.5		5.5	9.5		9.5	17.0			17.0	24.5			24.5	26.0			26.0
S60	10.0	12.0	14.5		14.5	18.0		18.0	19.5			19.5	19.0			19.0				
x̄	11.60	11.90			15.10			21.00				27.00				35.00				35.57

cont/

Table AP10(cont.) Shoenus nigricans

P \ t.n.	2.2.73. 1.1./t.	17.5.73. 1.1./t.	2.6.73. 1.1./t.	17.6.73. 1.1./t.	2.7.73. 1.1./t.	17.7.73. 1.1./t.	25.8.73. 1.1./t.
	1	1	1	1	1	1	1
T62	7.0						
T64	9.0	6.0	7.5	9.5	12.0	20.0	32.5
T66	34.0	31.0	32.5	39.5	45.0	55.5	69.0
T68	6.0						
T70	17.0	5.0	10.5	15.5	20.5	27.0	35.0
T71							
T73	5.0	2.5	1.5	2.0			
T75	9.0						
T77	5.0						
T79	6.0						
T82	8.0						
T84							
T86	11.0						
T88	19.0			3.0	3.5		4.5
T90	4.0						
$\bar{x}$	10.76	11.12	13.00	13.90	20.25	34.16	35.25
S61	20.0	23.0	27.0	37.0	53.0	81.0	97.5
S63	18.0	19.5	25.0	31.5	40.5	43.5	57.5
S65	17.0	13.5	17.0	22.5	30.5	37.0	51.5
S67	12.0	4.0	7.5	12.0	16.0	21.0	25.0
S69	32.0	8.5	12.0	24.5	37.5	46.5	61.0
S72	24.0	9.0	13.5	16.5	22.0	26.0	30.5
S74	5.0	18.0	23.5	27.0	30.0	38.5	51.5
S76	12.0		2.0	2.0			
S78	16.0	12.5	21.5	30.5	49.0	54.0	91.0
S80	20.0	13.5	18.0	27.0	31.0	36.5	51.5
S81	24.0	15.5	27.0	31.0	43.5	50.0	60.0
S83	12.0	2.5					
S85	16.0	23.0	27.5	35.5	35.0	49.0	77.5
S87	19.0	20.0	23.0	28.5	36.0	45.5	60.5
S89	15.0	17.0	22.5	29.0	34.0	43.0	53.5
$\bar{x}$	17.46	14.25	19.07	25.32	35.23	43.96	59.11

cont/

Table AP10 (cont.) *Tofieldia pusilla*

	2.2.73. l.l./t.	16.5.73. l.l./t.				1.6.73. l.l./t.				17.6.73. l.l./t.				2.7.73. l.l./t.				17.7.73. l.l./t.				25.8.73. l.l./t.			
p \ tn	1	1	2	3	Σ	1	2	3	Σ	1	2	3	Σ	1	2	3	Σ	1	2	3	Σ	1	2	3	Σ
T91	14.0	18.0				7.5			7.5	5.0			5.0	4.5			4.5	4.0			4.0				
T93	24.0	22.5				21.0			21.0	19.0			19.0	18.5			18.5	17.0			17.0	18.5			18.5
T95	14.0	8.0				10.0			10.0	5.5			5.5	2.5			2.5								
T97	25.0	25.0				21.0			21.0	22.0			22.0	19.5			19.5	19.5			19.5				
T99	26.0	31.5				36.0			36.0	42.5			42.5	41.0			41.0	53.0			53.0	44.5			44.5
T102	27.0	22.0				21.0			21.0	19.0			19.0	17.0			17.0	18.5			18.5	8.5			8.5
T104	20.0	6.5				6.5			6.5	5.0			5.0	2.5			2.5								
T106	14.0	13.0				13.5			13.5	10.0			10.0	7.5			7.5	5.5			5.5	7.0			7.0
T108	16.0	18.0				27.5			27.5	21.5			21.5	21.5			21.5	20.0			20.0				
T110	24.0	22.5				21.5			21.5	21.5			21.5	21.0			21.0	18.5			18.5				
T111	23.0	23.5				23.5	2.0		25.5	24.0	1.5		25.5	22.5	4.0		26.5	22.5	5.5		28.0	22.0	7.0		29.0
T113	34.0	8.0				3.0			3.0	2.0			2.0	2.0			2.0								
T115	12.0	13.5				13.5			13.5	14.5			14.5	19.5			19.5	31.5			31.5	41.0			41.0
T117	18.0	18.5				18.0			18.0	17.5			17.5	18.0			18.0	17.0			17.0	16.5			16.5
T119	11.0	16.5				9.0			9.0																
$\bar{x}$	20.13	17.80							16.96				16.46				15.82				21.13				23.57
S92	10.0	12.5			12.5	9.0			9.0	9.0			9.0	6.0			6.0								
S94	20.0	21.5			21.5	17.0	4.5		21.5	18.5	4.5		23.0	18.0	7.5		25.5	19.0	7.0		26.0	21.0	15.0		36.0
S96	22.0	29.5			29.5	31.5			31.5	34.5			34.5	34.5			34.5	36.0			36.0	42.0			42.0
S98	23.0	32.5			32.5	29.0			29.0	29.0			29.0	25.0			25.0	21.5			21.5				
S100	31.0	35.5			35.5	37.0			37.0	43.0			43.0	48.0			48.0	44.5			44.5	54.0			54.0
S101	24.0	21.5			21.5	22.5			22.5	20.0			20.0	19.5			19.5	21.0			21.0	21.5			21.5
S103	30.0	32.0			32.0	31.5			31.5	27.5			27.5	25.5			25.5	23.5			23.5		18.5		18.5
S105	35.0	37.0			37.0	43.0			43.0	38.0			38.0	42.5			42.5	43.0			43.0	40.0			40.0
S107	17.0	19.0			19.0	18.0			18.0	20.0			20.0	21.0			21.0	30.0			30.0	27.0			27.0
S109	21.0	24.0			24.0	22.0			22.0	20.5			20.5	17.5			17.5	17.5			17.5	10.0			10.0
S112	24.0	30.0			30.0	33.0			33.0	29.5			29.5	25.5			25.5	27.5			27.5	18.0			18.0
S114	19.0	20.5			20.5	24.0	2.0		26.0	20.5	2.0		22.5	16.5	2.0		18.5	17.5	2.5		20.0		3.5		3.5
S116	34.0	9.5			9.5	7.5			7.5	6.5			6.5												
S118	45.0	37.5	12.5	10.5	60.5	39.0	12.5	11.0	62.5	45.0	15.0	10.0	70.0	51.5	16.0	12.0	79.5	50.5	14.5	11.0	76.0	49.5	12.5	10.0	72.0
S120	13.0	16.5			16.5	15.0			15.0	17.0			17.0	21.0			21.0	25.0			25.0	20.0			20.0
$\bar{x}$	24.53				26.80				27.26				27.33				29.25				31.65				30.20

TABLE AP.11 Leaf biomass of Barley grown at Teesdale and Durham; in Teesdale soil (Ts), in Sunbiggin soil (Ss). (g/pot)

Repl.No.	at Teesdale		at Durham	
	Ts	Ss	Ts	Ss
1	.0488	.0429	.0446	.0584
2	.0330	.0542	.0433	.0357
3	.0504	.0326	.0442	.0494
4	.0497	.0208	.0620	.0267
5	.0686	.0339	.0216	.0497
6	.0397	.0403	.0269	.0503
7	.0424	.0398	.0352	.0312
8	.0637	.0662	.0376	.0664
9	.0511	.0412	.0392	.0447
10	.0590	.0289	.0650	.0366
11	.0575	.0325	.0597	.0418
12	.0466	.0441	.0564	.0457
13	.0576	.0414	.0358	.0419
14	.0382	.0641	.0523	.0627
15	.0846	.0385	.0334	.0426
16	.0432	.0567	.2004	.0548
17	.0385	.0551	.3997	.0458
18	.0405	.0459	.3094	.0423
19	.0306	.0399	.0627	.0424
20	.0421	.0391	.0584	.0423
21	.0599	.0615	.0279	.0714
22	.0422	.0358	.0403	.0580
23	.0426	.0488	.0343	.0588
24	.0307	.0431	.0388	.0481
25	.0581	.0519	.0222	.0478
x	.0488	.0440	.0741	.0478

L.S.D. between any pair of means

p	0.1	0.05	0.01	0.001
L.S.D.	0.022	0.026	0.034	0.045

Table AP.12 Growth data from Tofieldietalia collected during the 1974 cold frame experiment

Carex panicea

Mean individual dry weights (g)

	Repl. No.	Sampling dates 1/5	18/5	6/6	22/6	8/7	23/7	7/8	21/8
in metalliferous soil, uncovered	1	.0228	-	.0179	.0202	.0249	.0274	.0356	.0499
	2	.0458	.0364	.0191	.0242	.0297	.0322	.0417	.0392
	3	.0136	-	.0288	.0265	.0320	.0235	.0365	.0465
	4	-	.0215	.0501	.0378	.0254	.0283	.0509	.0433
	5	.0236	.0306	.0328	.0284	.0335	.0405	.0405	.0505
	6	.0260	.0417	.0296	.0352	.0196	.0219	.0480	.0381
	x̄	.0264	.0325	.0297	.0287	.0275	.0289	.0422	.0445
in metalliferous soil, covered	1	.0033	.0718	.0525	.0212	.0658	.0418	.0411	.0422
	2	-	.0862	.0235	.0563	.0462	.0322	.0359	.0400
	3	.0387	-	.0131	.0316	.0389	.0235	.0250	.0458
	4	.0115	-	-	.0501	.0263	.0283	.0336	.0626
	5	-	.0159	-	.0113	.0158	.0405	.0327	.0673
	6	.0922	.0295	.0259	.0077	.0367	.0219	.0626	.0689
	x̄	.0364	.0508	.0287	.0297	.0382	.0313	.0385	.0544
in non-metalliferous soil, uncovered	1	.0395	.0273	.0265	.0415	.0323	.0428	.0460	.0426
	2	.0585	.0230	.0255	.0285	.0450	.0430	.0370	.0425
	3	.0114	.0257	.0257	.0371	.0269	.0353	.0294	.0456
	4	.0319	.0155	.0124	.0324	.0332	.0345	.0396	.0375
	5	.0179	.0303	.0167	.0385	.0349	.0281	.0576	.0344
	6	.0203	.0104	.0286	.0337	.0233	.0226	.0363	.0406
	x̄	.0299	.0220	.0226	.0348	.0326	.0344	.0410	.0405
in non-metalliferous soil, covered	1	.0403	.0169	.0342	.0294	.0258	.0367	.0521	.0524
	2	.0371	.0328	.0375	.0524	.0317	.0410	.0520	.0270
	3	.0286	.0266	.0195	.0286	.0590	.0396	.0367	.0672
	4	.0190	.0172	.0234	.0170	.0395	.0377	.0563	.0369
	5	.0187	.0212	.0293	.0320	.0466	.0202	.0512	.0344
	6	.0124	.0226	.0187	.0230	.0304	.0452	.0368	.0372
	x̄	.0260	.0229	.0271	.0304	.0388	.0367	.0475	.0425

cont/

Table AP.12 (cont.)

Remainder sp.

Standing crops (g./dm^2)

		Repl. No.	Sampling dates 1/5	18/5	6/6	22/6	8/7	23/7	7/8	21/8
in metalliferous soil	uncovered	1	.1478	.2570	.5884	.5733	.7152	.6928	.8861	1.9063
		2	.3575	.5195	.5842	.5231	.7924	.5638	1.3951	1.4925
		3	.0420	.5509	.5137	.5370	.2478	.8088	.9148	.5691
		4	.2908	.5820	.9167	.7781	.6307	.9144	.5861	1.4681
		5	.3370	.4079	.4796	.7670	.5180	1.5431	.9450	1.2457
		6	.3362	.3561	.3422	.9286	.6950	1.1626	1.3127	.4491
		$\bar{x}$	.2516	.4456	.5708	.6845	.5998	.9476	1.0066	1.1885
	covered	1	.1490	.4402	.3679	.3014	.4447	.8552	.4203	.8911
		2	.0311	.6500	.3436	.3471	.1885	1.1561	.6171	.9147
		3	.0810	.2529	.2935	.3739	.5131	.1846	.5368	.6219
		4	.2533	.2933	.2055	.3643	.5454	.1550	.6335	1.3740
		5	.3018	.2832	.1224	.1292	.5200	.7532	.7443	.4898
		6	.4313	.2840	.1383	.1812	.2073	1.1111	1.1402	1.0830
		$\bar{x}$	.2079	.3613	.2452	.2828	.4032	.7025	.6213	.8957
in non-metalliferous soil	uncovered	1	.3668	.3540	.4095	1.2592	.4398	.8554	1.0839	.7027
		2	.0270	.4891	.3288	.3176	1.0080	.5188	.6119	.6032
		3	.1035	.6598	.4626	.5424	.7571	.5475	.6916	1.1397
		4	.2405	.2772	.1986	.8741	.7805	.4759	.8455	1.4836
		5	.9722	.8690	.3139	.5199	.9445	1.2256	1.6939	.6058
		6	.4544	.1190	.6298	.3615	.3523	.6102	.9637	1.0338
		$\bar{x}$	.3607	.4613	.3905	.6458	.7137	.7056	.9817	.9281
	covered	1	.3243	.3517	.6096	.6744	.7300	1.1827	1.1606	.6269
		2	1.0421	.9161	1.2076	.4925	.6962	1.7001	1.6412	.9612
		3	.1492	.6260	.4941	.6091	1.0083	1.2557	.7759	4.1613
		4	.1702	.3305	.5800	.5108	.7552	.5525	.4839	1.2939
		5	.4282	.4857	.1991	.7019	.4948	.4220	1.4902	.9888
		6	.2273	.2383	.2699	.4787	.5923	.6950	1.1425	1.2999
		$\bar{x}$	.3902	.4914	.5600	.5779	.7128	.9680	1.1157	1.5553

cont/

Table AP.13 Growth data from the Seslerio-Mesobromion collected during the 1974 cold frame experiment

Sesleria caerulea

Mean individual dry weights (g)

Soil	Treatment	Repl No.	1/5	18/5	6/6	22/6	8/7	23/7	7/8	21/8
			Sampling dates							
in metalliferous soil	uncovered	1	.0047	.0037	.0048	.0053	.0050	.0053	.0057	.0160
		2	.0080	.0040	-	.0075	.0102	.0056	.0154	.0057
		3	.0037	.0055	.0032	.0061	-	.0066	.0071	.0073
		4	.0037	.0036	.0058	.0094	.0115	.0095	.0057	.0072
		5	.0053	.0048	.0074	.0068	.0079	.0044	.0055	.0088
		6	.0047	.0064	.0081	.0063	.0074	.0083	.0138	.0135
		$\bar{x}$	.0050	.0047	.0059	.0069	.0084	.0066	.0089	.0097
	covered	1	.0055	.0080	.0098	.0098	.0218	.0129	.0265	.0267
		2	.0140	.0077	.0100	.0093	.0082	.0133	.0133	.0155
		3	.0057	.0209	.0119	.0124	.0200	.0229	.0125	.0194
		4	.0069	.0102	.0123	.0129	.0165	.0121	-	.0273
		5	.0067	.0325	.0129	.0077	.0161	.0035	.0252	.0119
		6	.0102	.0094	.0128	.0108	.0146	.0257	.0162	.0258
		$\bar{x}$	.0082	.0148	.0116	.0105	.0162	.0151	.0207	.0211
in non-metalliferous soil	uncovered	1	.0132	.0096	.0086	.0252	.0189	.0175	.0199	.0184
		2	.0039	.0081	.0112	.0114	.0123	.0140	.0184	.0066
		3	.0059	.0097	.0103	.0054	.0219	.0142	.0229	.0226
		4	.0117	.0103	.0111	.0169	.0138	.0276	.0169	.0114
		5	.0132	.0096	.0126	.0173	.0087	.0186	.0127	.0168
		6	.0089	.0156	.0074	.0268	.0276	.0214	.0133	.0158
		$\bar{x}$	.0095	.0105	.0102	.0172	.0172	.0189	.0173	.0153
	covered	1	.0048	.0078	.0097	.0198	.0173	.0159	.0273	.0484
		2	.0068	.0056	.0092	.0176	.0176	.0154	.0193	.0251
		3	.0065	.0108	.0095	.0209	.0237	.0236	.0229	.0682
		4	.0070	.0079	.0124	.0378	.0180	.0189	.0096	.0300
		5	.0106	.0158	.0074	.0223	.0191	.0228	.0294	.0314
		6	.0230	.0176	.0115	.0236	.0079	.0184	.0371	.0304
		$\bar{x}$	.0098	.0109	.0099	.0237	.0173	.0192	.0243	.0389

cont/

Table AP.13 (cont.)

Festuca ovina

Mean individual dry weights (g)

	Repl. No.	1/5	18/5	6/6	22/6	8/7	23/7	7/8	21/8
in metalliferous soil, uncovered	1	.0011	.0013	.0025	.0027	.0024	.0024	.0035	.0054
	2	.0025	.0022	.0027	.0027	.0030	.0025	.0037	.0035
	3	.0024	.0021	.0021	.0039	.0028	.0028	.0037	.0032
	4	.0018	.0017	.0020	.0016	.0045	.0042	.0026	.0035
	5	.0020	.0020	.0026	.0036	.0039	.0030	.0031	.0037
	6	.0017	.0026	.0025	.0024	.0021	.0034	.0052	.0039
	$\bar{x}$	.0019	.0020	.0024	.0028	.0031	.0030	.0036	.0039
in metalliferous soil, covered	1	.0028	.0020	.0019	.0027	.0035	.0026	.0048	.0059
	2	.0032	.0019	.0017	.0026	.0023	.0033	.0056	.0042
	3	.0022	.0022	.0027	.0029	.0074	.0053	.0037	.0068
	4	.0023	.0040	.0022	.0044	.0030	.0047	.0037	.0060
	5	.0025	.0029	.0022	.0032	.0046	.0032	.0043	.0036
	6	-	.0028	.0012	.0043	.0024	.0051	-	-
	$\bar{x}$	.0026	.0026	.0020	.0033	.0038	.0040	.0044	.0053
in non-metalliferous soil, uncovered	1	.0023	.0034	.0031	.0051	.0032	.0049	.0076	.0026
	2	.0018	.0042	.0042	.0055	.0078	.0030	.0025	.0085
	3	.0028	.0035	.0037	.0033	.0039	.0043	.0066	.0066
	4	.0032	.0048	.0028	.0028	.0032	.0041	.0050	.0064
	5	.0025	.0064	.0065	.0028	.0057	.0057	.0031	.0051
	6	.0022	.0053	.0032	.0055	.0073	.0061	.0038	.0050
	$\bar{x}$	.0025	.0046	.0039	.0042	.0052	.0047	.0048	.0057
in non-metalliferous soil, covered	1	.0018	.0027	.0039	.0055	.0078	.0042	.0050	.0051
	2	.0025	.0027	.0039	.0047	.0043	.0032	.0039	.0077
	3	.0017	.0039	.0029	.0066	.0055	.0023	.0033	.0065
	4	.0022	.0016	.0023	.0049	.0043	.0041	.0053	.0083
	5	.0031	.0036	.0029	.0035	.0051	.0048	.0063	.0065
	6	.0029	.0024	.0035	.0054	.0064	.0056	.0052	.0069
	$\bar{x}$	.0024	.0028	.0032	.0051	.0056	.0040	.0048	.0068

cont/

Table AP.13 (cont.)

Carex panicea

Mean individual dry weights (g)

	Repl. No.	1/5	18/5	6/6	22/6	8/7	23/7	7/8	21/8
in metalliferous soil, uncovered	1	.0024	.0114	.0072	.0093	-	.0053	-	.0145
	2	.0081	.0097	.0141	.0135	.0258	.0182	.0135	.0282
	3	.0122	.0096	.0186	.0091	.0329	.0151	.0174	.0195
	4	.0083	.0056	.0122	.0214	.0140	.0155	.0238	.0093
	5	.0087	.0067	.0114	.0096	.0197	.0333	.0155	.0090
	6	.0100	.0040	.0219	.0077	.0127	.0157	.0213	.0159
	$\bar{x}$	.0083	.0078	.0142	.0118	.0210	.0172	.0183	.0161
in metalliferous soil, covered	1	.0279	.0149	.0199	.0257	.0263	.0235	.0275	.0153
	2	.0207	.0127	.0157	.0132	.0224	.0318	.0243	.0342
	3	.0614	.0155	.0151	.0164	.0218	.0292	.0238	.0408
	4	.0104	.0088	.0074	.0297	.0171	.0350	.0305	.0297
	5	.0162	.0311	.0237	.0141	.0295	.0271	.0321	.0350
	6	.0186	.0148	.0175	.0185	.0201	.0276	.0375	.0505
	$\bar{x}$	.0259	.0163	.0165	.0196	.0229	.0290	.0293	.0342
in non-metalliferous soil, uncovered	1	.0083	.0026	.0085	.0177	.0274	.0223	.0378	.0542
	2	.0082	.0093	.0100	.0218	.0286	.0331	.0446	.0721
	3	.0274	.0028	.0215	.0162	.0153	.0294	.0106	.0238
	4	.0130	.0048	.0065	.0143	.0282	.0244	.0144	.0146
	5	.0214	.0141	.0101	.0254	.0131	.0287	.0288	.0537
	6	.0025	.0130	.0102	.0294	.0206	.0155	.0273	.0294
	$\bar{x}$	.0135	.0078	.0111	.0208	.0222	.0256	.0272	.0413
in non-metalliferous soil, covered	1	.0074	.0126	.0122	-	.0174	.0243	-	.0363
	2	.0049	.0131	.0311	.0145	.0200	.0286	.0330	.0667
	3	.0160	.0125	.0080	-	.0222	.0237	.0175	.0263
	4	.0036	.0148	.0048	.0424	.0189	.0308	-	.0313
	5	.0061	.0059	.0031	.0090	.0205	.0348	.0307	.0242
	6	.0226	.0059	.0187	.0234	.0321	.0199	.0365	.0282
	$\bar{x}$	.0101	.0108	.0130	.0223	.0218	.0270	.0294	.0355

Cont/

Table AP.13 (cont.)

Remainder sp.

Standing crops (g./dm^2)

		Repl. No.	1/5	18/5	6/6	22/6	8/7	23/7	7/8	21/8
			Sampling dates							
in metalliferous soil	uncovered	1	.0464	.2008	.4744	.6482	.3990	.4498	.7348	.4426
		2	.0874	.5803	.4815	.7354	.3367	.7950	.8729	.5723
		3	.2004	.3936	.2008	.4198	.9380	.5474	.6136	.8299
		4	.1686	.3493	.4766	.5958	.9414	.8374	.4335	.9709
		5	.2120	.3775	.4606	.4392	1.0011	.6745	.6811	.4799
		6	.3481	.8333	.5189	.2409	.5727	.6956	.7775	1.3071
		$\bar{x}$	.1771	.4558	.4338	.5132	.6981	.6666	.6856	.7671
	covered	1	.1560	.8181	.1071	.3205	.7766	.6338	.5978	1.1688
		2	.1255	.2894	.3098	.3534	.4223	.2830	.4299	.4860
		3	.0565	.3762	.2539	.2186	.4078	.5297	.3918	.4680
		4	.1689	.3858	.3270	.4969	.2484	.4778	.5118	1.1498
		5	.1889	.6420	.2934	.2763	.3109	.4254	.3981	.5200
		6	.2361	.8241	.1385	.2655	.4368	.7993	.9796	1.2012
		$\bar{x}$	.1553	.5559	.2383	.3219	.4338	.5248	.5515	.8323
in non-metalliferous soil	uncovered	1	.0827	.3128	.4834	.4842	.7242	.8912	1.0025	.6044
		2	.1195	.2186	.3933	.4961	.6785	.4370	.8976	.8083
		3	.1662	.2993	.2848	.4597	.7716	.4966	.8190	.9597
		4	.1303	.0651	.5391	.4015	.7027	.4693	.5152	1.0344
		5	.1634	.3609	.4662	.6322	.3947	.6919	.6346	.8733
		6	.1991	.4756	.2242	.2312	.4858	.5495	1.0267	.3496
		$\bar{x}$	.1435	.2887	.3985	.4508	.6263	.5893	.8159	.7716
	covered	1	.0843	.3314	.3634	.7926	.4424	.7582	1.0358	.5495
		2	.1192	.3128	.2940	.4942	.4072	.4225	.9786	1.0803
		3	.0780	.1927	.2417	.6163	.7836	.6138	.4172	.7912
		4	.2370	.3319	.4503	.7526	.5732	.8104	.7123	.6083
		5	.0859	.4410	.3203	.4382	.4188	.5066	.9544	1.8425
		6	.2474	.4249	.3176	.3483	1.1297	.5129	.8624	1.4773
		$\bar{x}$	.1420	.3391	.3312	.5737	.5592	.6041	.8268	1.0582