and the extent of these differences during a relatively short interval of time, as well as giving information on plant successions in grassland communities.

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The biology of weeds in hill pasture

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INTRODUCTION

Present methods for the improvement of hill land are based on the use of lime and phosphate to bring soils to a level of fertility at which they will support the growth of grasses which have been developed for lowland pastures, and white clover. In addition, the land must be fenced to introduce a measure of grazing control and further fertilizer applications are required at regular intervals, but even so the maintenance of the introduced species against competition from the indigenous vegetation requires management which may not be possible in the context of upland farming. The amount of improvement which is possible is restricted by the requirement for a large initial capital expenditure, which cannot always be generated from land producing a low gross annual output per unit area, and the necessity for regular recurrent inputs from a farming system where profits fluctuate markedly.

In the west of Scotland, much hill land is dominated either by *Molinia caerulea* (L.) Moench on peat, or by bracken (*Pteridium aquilinum* (L.) Kuhn), with or without an underlying sward, on acid brown earths. Adverse weather conditions impose restraints on the total potential output, and also many of the bracken-dominated areas, which offer the greatest possibilities for improvement, are too steep or too rocky for methods which involve the use of wheeled vehicles to cover the whole area to be employed. Current work is therefore concerned with low-cost, low-weight input improvements which can be carried out over large areas by aerial application, or on a small scale by men on foot working from a vehicle situated at a central point, and which will maintain themselves against the encroachment of indigenous plants without the necessity for regular further expenditure.

THE CONTROL OF BRACKEN

After years of trials of many chemical compounds, it can now be said that economic control of bracken by herbicides is feasible. Asulam is being widely used for this purpose, and when applied between full frond expansion and the onset of senescence at a rate of 4 kg a.i./ha gives acceptable control for some years (Anon., 1974*a*). While there is no doubt that the control of bracken by asulam brings benefits in terms of increased availability of grass, easier shepherding, and the elimination of poisoning risks, in terms of increasing the stocking capacity of hill land it seems to be most valuable to those farmers with sufficient in-bye fields to provide adequate winter keep. In the west of Scotland, most farms have only limited amounts of in-bye land in relation to their hill acreage, and their stocking capacity is determined by the number of stock which the hill will support over the winter, a factor which is not significantly affected by bracken clearance. In such cases, there is an urgent need to improve the quality and quantity of winter feeding available on the hill.

Glyphosate has also been shown to be effective in controlling bracken (Anon., 1974*b*), and although fewer data are available than for asulam, a study of its effect on the rhizome system (Williams & Foley, 1975) suggests that it will prove at least comparable in suppressing frond regrowth. It is much more drastic in its effects on the sward than asulam, however (Williams, 1974), although the degree of sward kill is influenced greatly by the amount of frond cover and by the time of application. July applications to a dense bracken canopy have resulted in little grass kill, while August applications have had selective effects. *Deschampsia* spp. and *Festuca rubra* L. appear resistant, and as these provide better winter grazing than other hill grasses (Black, 1968), their spread improves pasture quality. *Holcus mollis* L., if present in the original sward, can recolonize cleared areas rapidly. Milner & Gwynne (1974) have shown that the intake of this grass by sheep is reduced in summer months, presumably because it is less palatable than other species, but that it is then grazed in winter when little else is available. Although its digestible organic matter content declines markedly, it is better in this respect than *Agrostis tenuis* Sibth. (Black, 1968), and by encouraging the grazing of *Agrostis* in summer, and remaining available for use in winter, *H. mollis* can promote more efficient utilization of dry matter.

RECLAMATION OF BRACKEN LAND

In the absence of *H. mollis*, the recolonization of areas cleared of bracken proceeds slowly, and the alternative is to reseed. S. 143 cocksfoot (*Dactylis glomerata* L.) has been shown to survive on deep peat (Hunt, 1962), and a trial was established to investigate its potential for the reclamation of land cleared of bracken.

Table 1. *Recolonization of herbicide-treated, burnt plots* (%)

Site	Treatment		*Dactylis*	Other grasses	Forbs	Rock	Bare
Moniaive	Asulam	Control	—	32·9	6·8	14·5	45·8
		Resown	15·8	30·6	3·9	11·5	38·2
	Glyphosate	Control	—	4·7	7·2	9·0	79·1
		Resown	39·9	7·6	9·3	12·1	31·1
Anwoth	Asulam	Control	1·2	40·6	34·7	—	23·5
		Resown	15·9	38·3	31·8	—	14·0
	Glyphosate	Control	—	18·4	24·5	—	57·1
		Resown	47·6	19·8	13·7	—	18·9

In August 1973, 1250 m² bracken-infested plots at Moniaive, Dumfriesshire, and Anwoth, Kirkcudbrightshire, were sprayed with asulam at 4 kg a.i./ha or glyphosate at 2 kg a.i./ha. During the following winter, some plots were burnt to remove litter, and in April 1974, S. 143 was sown at 35 kg/ha. In August, assessments of sward composition were made, and the results are presented in Table 1. Grazing cages were set up in September to provide yield data.

The results of this trial to date show that sowing into a mat of existing vegetation is ineffective, as little cocksfoot was found in unburnt plots. Of the plots which were burnt, those treated with glyphosate gave better establishment if the ground was level; on slopes, wash of seeds occurred and better ground cover was seen in asulam-treated plots, which retained more of their original vegetation. During the period September 1974 to April 1975, which was a very mild winter with little frost, cages showing a mean 50% ground cover by cocksfoot produced 140 kg/ha dry matter, a significant contribution at this time of year, whereas there was no measurable growth in indigenous grasses.

THE ROLE OF *LOTUS* SPP.

One of the benefits of treating hill land with lime and phosphate has been the encouragement of white clover to provide a source of much-needed protein. Under more acid conditions, *Lotus* species provide a possible alternative and investigations have been proceeding for some

years (Charlton, 1971) on *L. corniculatus* L. and *L. uliginosus* Schk. (also referred to as *L. pedunculatus* Cav. (Forde, 1974)). No variety of *L. corniculatus* has yet been developed which will establish and grow under conditions of uncontrolled sheep grazing, but *L. uliginosus* has shown more promise.

In April 1974, establishment trials of *L. uliginosus* cv. Grasslands Maku were sown at 5 kg/ha on areas which had been cleared of bracken, and also on *Molinia*-dominated areas which had been treated with glyphosate at 2 kg a.i./ha in August 1973. The seed was inoculated, but no fertilizer treatment was applied.

The cultivar normally has a hard seed content of *c.* 60% and germination was therefore irregular, but sufficient plants became established to show that they were grazed readily. On the *Molinia* areas, grazing was less intense as there was standing water on occasions. The plants die back in winter and no data can be given for establishment, but a number of plants were showing regrowth in April 1975, even on bracken land. In New Zealand, Grasslands Maku has outyielded Huia white clover under certain conditions (Lambert, Boyd & Brock, 1974), and trials are in progress to determine its value in United Kingdom agriculture.

CONCLUSIONS

Increased output from hill land, especially in the west of Scotland, is largely dependent on the provision of better-quality herbage especially outside the May–August period during which the indigenous vegetation makes almost all its annual growth, but the scope for improvement is limited by low returns per unit area as compared with lowland grassland.

S. 143 cocksfoot and Grasslands Maku trefoil, by being capable of establishing in the absence of fertilizer applications under conditions of uncontrolled sheep grazing, provide a basis for the improvement at relatively low cost of areas at present dominated by bracken or *Molinia*, following herbicide treatment. Cocksfoot will grow at lower temperatures than indigenous grasses, while trefoil provides a source of protein, and although much more investigation is needed into their optimum utilization, it appears that radical changes in present husbandry methods will not necessarily be required.

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