Effects of Subsoil Draining on Heather Moors in Scotland

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Highlight: Subsoil draining improved the growth and nutrient content of heather on Scottish moors covered by shallow peat, where drainage is impeded by an iron pan underneath. On such moors, subsoiling has significant advantages over conventional open drains.

Heather (*Calluna vulgaris*) is the dominant plant on many Scottish moors. On such moors, it is the main food of red grouse (*Lagopus lagopus scoticus*) and mountain hares (Jenkins et al. 1963; Hewson 1962), and of red deer (*Cervus elaphus*), sheep, and cattle in winter (Staines 1970; Thomas 1956). The number of grouse on a moor is related to the pattern of burned patches and to the cover, shoot length, and nutrient content of the heather there (Miller et al. 1966; Picozzi 1968; Moss 1969). Heather on wet, poorly drained, peaty moors grows less vigorously than on drier moors (Gimingham 1960) and fewer grouse occur on these wet moors (Watson and O'Hare 1973). Knowing this, land managers frequently drain wet moors in an attempt to increase grouse stocks.

The usual open drain has disadvantages. Although it obviously improves heather growth, the improvement is limited to about 0.5 m either side of each ditch. Some surface water is removed by open drains, but most of the ground remains boggy, because lateral percolation in peat is very slow (Donald 1973). Also, the artificial gullies formed by the drains can cause serious erosion, and young grouse chicks may fall into the drains and drown.

On many wet moors, poor natural drainage is caused by a shallow iron pan lying under a foot or two of peat. When planting trees on such ground, foresters improve drainage by using a plough with a deep, narrow tine which breaks up the iron pan but scarcely disturbs the surface vegetation. It occurred to us that this technique might be used to improve the growth of heather (Figs. 1 and 2).

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Fig. 1. *Subsoiler in action on typical heather moor which can benefit from subsoil draining.*

Methods

Forty hectares of a heathery hillside at Dunphail estate, near Forres in northeast Scotland, were subsoiled in March 1969, using a hydraulically operated subsoiler drawn by a crawler tractor. The aim was to shatter the iron pan which lay at a depth of about 0.5 m. Cuts

Fig. 2. *Subsoiling tine.*

were made at intervals of 4, 9, and 14 m apart on different parts of the ground, and at an angle of about 20° with the contours. In February 1974, 40 ha of heathery hillside at Tulchan estate, near Grantown, were tine ploughed, with cuts at interval of 14 m running at right angles to the contours.

We inspected both areas on June 30 and July 1, 1975. At both moors a clear difference was visible between subsoiled and adjacent areas. At Dunphail, the entire area, irrespective of the distance between cuts, showed visibly improved heather growth. At Tulchan, distinct bands about 0.6 m wide were visible on either side of the new cuts.

We sampled the heather at Dunphail along 3 transects on different-aged patches of heather. Ten 0.25-m^2 quadrats were dropped outside and 10 inside the subsoiled area, at intervals of 10 paces. Heather cover was estimated by eye to the nearest 10%, and within each quadrat the height of the heather canopy was measured in centimeters and the length of five long shoots (Gimingham 1960) measured to the nearest centimeter. The heather's age was classified according to Watt (1955).

At Tulchan we followed a similar procedure, except that we took two different kinds of sample from inside the subsoiled area, dropping alternate quadrats adjacent to the tine cuts and also halfway between cuts. The intention was to compare the visible bands along the cuts with heather which was not visibly affected.

Within each quadrat, a handful of heather was cut for later chemical analysis. In the laboratory, the top centimeter was snipped off each heather shoot until 2 g (fresh weight) had been collected from each sample. These subsamples were then combined into six experimental and nine control samples, dried at room temperature, milled to pass through a 1-mm sieve and analyzed for N, P, and Ca.

Results

The effect of subsoiling was to increase the length (Table 1) and the nitrogen and phosphorus content (Table 2) of heather shoots at both areas. Height had increased at Dunphail 6 years after treatment but not at Tulchan 18 months after subsoiling. There was also a small increase in cover at Dunphail which did not approach statistical significance within any one sample, but was significant ($P < 0.001$) when the three experimental means were compared with the three control means using a paired *t*-test.

The result for shoot length was slightly complicated by the lack of any differences in sample 2 at Dunphail. However, the height did differ, so that there had evidently been a difference in growth in past years.

Discussion

We did not count the grouse on the subsoiled areas, but the head keeper at Dunphail considers that treatment has improved the shooting there relative to the rest of his ground. We should

Table 1. Effect of subsoil draining on heather 6 years (Dunphail) and 18 months (Tulchan) after treatment.

		Mean shoot length (cm)			Mean height (cm)			Mean cover (%)		
Transect	Age-class of heather	Treated	External[a] control	Internal[b] control	Treated	External control	Internal control	Treated	External control	Internal control
Dunphail 1	Mature/degenerate	2.38	1.17***	—	22.0	22.4	—	59	54	—
2	Early building (c 5 years)	3.24	3.46	—	23.4	18.3*	—	83	77	—
3	Mature	2.56	1.78	—	36.3	26.8**	—	99	93	—
	Combined[c] probability		***			**			see text	
Tulchan 1	Late building	2.52	1.47[t]	1.87	26.0	22.0	25.2	58	56	53
2	Degenerate	2.10	1.70	1.53[t]	31.0	31.0	31.7	57	54	53
3	Degenerate	3.10	2.40*	1.80**	33.5	35.0	33.3	56	57	56
	Combined[c] probability		*	**						

[a]Outside tined area.
[b]Between tined strips.
[c]According to $X^2 = -2/np$.
[t]Two-tailed probability that this figure differs from the treated value <0.1 (by *t*-test).
$*P<0.05$, $**P<0.01$, $***P<0.001$.

Table 2. Effect of subsoil draining on chemical composition (% dry matter) of heather shoot tips.[1]

	Nitrogen			Phosphorus			Calcium		
Transect	Treated	External control	Internal control	Treated	External control	Internal control	Treated	External control	Internal control
Dunphail 1	1.55	1.37	—	0.13	0.094	—	0.43	0.49	—
2	1.73	1.69	—	0.15	0.15	—	0.42	0.41	—
3	1.63	1.56	—	0.15	0.13	—	0.44	0.47	—
Tulchan 1	1.84	1.56	1.58	0.16	0.14	0.15	0.41	0.42	0.38
2	1.61	1.56	1.48	0.15	0.14	0.13	0.41	0.37	0.43
3	1.88	1.63	1.64	0.17	0.15	0.15	0.42	0.41	0.41

[1]The treated heather contained more nitrogen and phosphorus ($P<0.05$, by paired *t*-test), but not Ca, than the external control.

certainly expect this from the improved performance of the heather on the drained ground. We should also expect better performance by mammals.

The technique is of value only when the iron pan is broken up by the tine, that is, on pans overlain by a maximum of 0.5 m of peat. The areas of Scotland with much ground like this and most likely to benefit from tining are the Moorfoots, Lammermuir, and Sidlaw Hills and hill land east of the A9 road north of Blair Atholl. On such suitable ground, subsoiling at an acute angle with the contours appears to remove water more quickly and completely than open drains in the same place, with less danger of gully erosion.

Additional advantages of subsoiling are that the surface of the moor is not seriously disturbed, so that access by wheeled vehicles is not affected, and that cattle and sheep do not damage the drainage channels, as happens with open drains.

More work should be done to see how long subsoiling has an effect, what the optimum distance between cuts is, and at what angle the cuts should cross the contours. For practical purposes the best recommendation we can give at the moment is that cuts need be no closer than 14 m apart, and should be made at an acute angle with the contours.

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THESIS: TEXAS A&M UNIVERSITY

A Biosystematic Study of the *Schizachyrium cirratum-Schizachyrium sanguineum* **complex (Poaceae),** by Stephan Lavor Hatch, PhD, Range Science. 1975.

A taxonomic investigation of the *Schizachyrium cirratum-Schizachyrium sanguineum* complex was made. The following taxa were included: *S. cirratum, S. hirtiflorum, S. sanguineum,* and *S. semiberbe*. The above taxa were compared with *S. scoparium* var. *neomexicanum*, which is similar morphologically. Two varieties were delimited in *S. cirratum, S. cirratum* var. *carratum* and *S. cirratum* var. *mexicanum*. The remaining taxa, excluding *S. scoparium* var. *neomexicanum*, were included in one species, *S. sanguineum* with three varieties, *S. sanguineum* var. *sanguineum, S. sanguineum* var. *domingense,* and *S. sanguineum* var. *oligostachyum*.

Anatomical studies did not provide any new character combination to delimit the taxa. The culms had solid internodes with three peripheral rings of vascular bundles. Transverse sections of the leaf showed approximately a 3:1 ratio of minor to major vascular bundles, radiating chlorenchyma, a single bundle sheath per vascular bundle, and bulliform cells in groups of 4–7. The epidermis was typical panicoid, wth macro- and microhairs, low-dome shaped or triangular subsidiary cells, short cells dumbell or cross shaped or occasionally nodular, and short cells in rows of 2- many.

Cytological studies confirm previous chromosome counts of: $2n=20$ for *S. cirratum* var. *cirratum*, $2n=40$ for *S. scoparium* var. *neomexicanum*, $2n=80$ for *S. sanguineum* var. *sanguineum*, and $2n=100$ for *S. sanguineum* var. *domingense*. New chromosome counts reported: $2n=40$ for *S. sanguineum* var. *sanguineum* and $2n=70$ for *S. sanguineum* var. *domingense*. Abnormal meiotic divisions were observed in the $2n=100$ *S. sanguineum* var. *domingense* and anatomical sections show these plants to be apomictic (aposporous).

To determine patters of variation within and between species and varieties, population samples were collected in Texas, Arizona, New Mexico, and Mexico. Population data involved measurement and comparison of many characters, including vestiture of the first glume, length of the first glume of the sessile spikelet, length of the sterile spikelet awn, length of the inflorescence, length of the pedicel, and length and vestiture of the rachis internode.

The analysis showed that the taxa commonly recognized as species were highly variable morphologically and that some were distinguished by characters with overlapping ranges of variation not attributable to distribution. As a result of the investigation, fewer species are recognized, with intergrading variants being designated as varieties.