# PART II

## Research Undertaken for the Forestry Commission at Universities and other Institutions

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# NUTRITION AND FOREST SOILS

## NUTRITION EXPERIMENTS IN FOREST NURSERIES

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### Sulphur

Sulphur is an essential nutrient, required by plants in about the same weight as phosphorus. Coal, oil and unpurified natural gas contain much S and in most industrial countries burning these fuels puts enough sulphur in the air and rain to provide for crops; sulphur is also supplied by sulphates used as fertilisers (e.g. calcium sulphate in ordinary superphosphate). The cleaning of combustion gases to make the air purer, and the change to more concentrated fertilisers that contain little or no S, increase the possibility of responses to sulphur. What we think are the first effects in England of applying sulphur to soil in field experiments were obtained with conifer seedlings and radishes at Wareham, Dorset.

*Sitka Spruce*

In 1965 Sitka spruce (*Picea sitchensis*) seedlings grown in very acid soil (pH in 0·01 *M* $CaCl_2$ 3·3–3·5) at Wareham gave height responses to graded additions of calcium sulphate (*Rothamsted Report* for 1965, p. 62), which were attributed to calcium acting as a nutrient. In the same experiment, improvement in seedling colour also closely followed the amounts of calcium sulphate given, and it was suspected that the pale green of the untreated seedlings was associated with sulphur deficiency. Later results from several small trials with Sitka spruce seedlings testing calcium sulphate, sodium sulphate and calcium carbonate, showed that calcium improved growth but not colour, whereas sulphur improved colour but not growth.

In 1967, healthy green seedlings grown with potassic superphosphate (a mixture of 90 per cent single and 10 per cent triple superphosphate plus KCl) supplying 14 g S/m$^2$ contained 0·18 per cent sulphur in needle dry matter, whereas needles from pale plants on plots with sulphur-free fertilisers contained 0·09 per cent sulphur; needles from plots with similar fertilisers but with 14 g S/m$^2$ contained between 0·10 and 0·16 per cent when S was supplied as sodium sulphate and 0·16 per cent S when calcium sulphate was given. This agrees fairly well with the values of $<0·13$ per cent S given by Ingestad as indicating deficiency and 0·13–0·18 per cent S as an intermediate range for Norway spruce (*Picea abies*) grown in solution culture (*Meddn St. Skogsforsk Inst.* (1962), 51 No. 7, 150 pp). The only published reference to sulphur deficiency

in conifers in Britain seems to be the transient yellowing of Corsican Pine (*Pinus nigra* var. *calabrica*) observed by Binns and Keay on "no sulphur" plots on the Culbin sand dunes in Scotland (*Rep. For. Res., Lond.*, 1962, p. 87).

To elucidate further the effects of S and Ca, Sitka spruce seedlings treated with Ca- and S-free fertilisers (consisting of magnesium ammonium phosphate, potassium metaphosphate and top-dressings of either urea or ammonium nitrate) were compared with those given additional calcium carbonate, sodium sulphate, calcium sulphate ($CaSO_4.\frac{1}{2}H_20$), or flowers of sulphur (pure S). The sulphur concentrations in seedling needles (Table 27) agreed well with earlier results and ran parallel to the colour scores, except that the slight improvement from sodium sulphate was not reflected in larger percentage S. Heights of seedlings at the end of the season confirmed the vigour scores, which showed that calcium (whether applied as calcium carbonate or as calcium sulphate) but not sulphur in any form, improved growth. (Benzian, Bolton and Freeman).

TABLE 27

EFFECT OF SULPHUR AND CALCIUM ON SITKA SPRUCE SEEDLINGS, WAREHAM, 1968

| Treatments | Applied (g/m²) | | August | | | End-of-season | |
|---|---|---|---|---|---|---|---|
| | Ca | S | Colour score* | Vigour score | % S (needles) | Height (cm) | pH ($CaCl_2$) |
| None | — | — | 2·4 | 2·1 | 0·092 | 9·2 | 3·2 |
| $CaCO_3$ | 24 | — | 2·0 | 2·8 | 0·082 | 9·9 | 3·5 |
| $Na_2SO_4$ | — | 19 | 3·3 | 1·8 | 0·096 | 9·2 | 3·2 |
| $CaSO_4.\frac{1}{2}H_2O$ | 24 | 19 | 4·2 | 3·0 | 0·170 | 10·3 | 3·3 |
| Sulphur† | — | 19 | 5·0 | 2·2 | 0·196 | 7·0 | 3·1 |
| | | | Standard errors | | ± 0·0048 | ± 0·15 | ± 0·03 |

*Largest value = darkest green.
†As flowers of sulphur.

Many seedlings on plots treated with flowers of sulphur and a few seedlings on those with calcium sulphate (all with basal ammonium nitrate) had the characteristic tip-burn symptoms of copper deficiency. The tops of these plants contained only about 1 ppm Cu (in dry matter) whereas symptom-free seedling tops on calcium sulphate plots contained 3 ppm. These values agree fairly well with those of Benzian and Warren (*Nature, Lond.* (1956) **178**,864). (Benzian, with Hill, Biochemistry Department, Rothamsted).

*Radish and Lupin*

These species were expected to need more sulphur than Sitka spruce, and were used as test crops in two small trials at Wareham in 1968 on plots exhausted by fifteen years of continuous cropping without fertilisers. Sulphur-free basal NPKMg fertilisers were used. Table 28 shows that 19 g/m² of elemental sulphur increased dry matter yields of the first radish crop (planted in mid-May and harvested 6 weeks after) by about 14 per cent. This seems to be the first statistically significant yield response by any crop in the United Kingdom to sulphur applied in the field. Plants from the untreated plot con-

tained only 0·22 per cent S, much less than is usual in brassicae. A second radish crop grew badly on the plots given sulphur, possibly because the sandy soil had become very acid. However, a third crop planted in mid-August after liming, also yielded less dry matter on the sulphur-treated than on untreated plots; the radishes from this planting on the untreated plots contained more sulphur than those of the first planting on treated plots, showing that some sulphur had become available to the plants during the summer either from rain, the atmosphere or by mineralisation of organic-S.

TABLE 28

SULPHUR AND YIELDS AND COMPOSITION OF RADISHES AND LUPINS

| S applied g/m² | Radish | | | | Lupin | |
|---|---|---|---|---|---|---|
| | 1st crop | | 3rd crop | | | |
| | Yield* | %S | Yield* | %S | Yield* | %S |
| 0 | 202 | 0·22 | 191 | 0·76 | 519 | 0·22 |
| 19 | 231 | 0·73 | 145 | 0·96 | 386 | 0·45 |
| Standard errors | ± 4·1 | ± 0·046 | ± 8·6 | ± 0·060 | ± 34·4 | ± 0·022 |

*Yields as g dry matter/m²

Yellow lupins planted in May and harvested in late August yielded less on the sulphur-treated than on the untreated plots, again possibly because of acidity (soil pH measured in water was 4·1 in treated and 4·7 in untreated plots after cropping). (Bolton and Benzian.)