Growth Check of Norway spruce and Scots pine due to Potassium Deficiency

By N. O'CARROLL *

Summary

A condition of checked growth associated with chlorotic foliage of Norway spruce and Scots pine on *Phragmites* peat appeared at first examination to be due to moisture deficiency. Detailed investigation did not support this hypothesis but foliar analysis and, to a lesser extent, soil analysis pointed to potassium deficiency. The appearance of the trees was quickly improved by applications of sulphate of potash.

INTRODUCTION

LATE in 1961 attention was drawn to an area in Emo State Forest (Moanvane property) where tree growth was uneven, some parts being poor and apparently getting worse.

The 275 acre property was bought by the Forestry Division in 1940. The soil is a well humified *Phragmites* peat overlying calcareous sand and gravel. The peat varies in depth but is generally more than 3 feet and rarely less than 1 foot deep. An extensive system of drainage ditches at an average distance of 150 to 200 yards apart suggests that the area had once been reclaimed for agricultural purposes. Scots pine shelterbelts associated with some of these ditches are about 100 years old.

Just before its purchase by the Forestry Division the area was being used for the production of hay in the wetter parts and for tillage crops (probably potatoes and oats) where drainage was better. At that time it was expected that drainage would be a problem because of the flatness and relatively low-lying situation.

The species used in afforestation were Norway spruce (*Picea abies* (L.) Karst) and Scots pine (*Pinus sylvestris* L.) both in pure crops and in mixture. Reports on record indicate that early growth, particularly of the spruce, over much of the area was not satisfactory.

In the years following planting the drainage system was intensified, with main drains $2\frac{1}{2}$ to 4 feet deep and feeders about $1\frac{1}{2}$ feet deep. In parts of the area these drains were placed as close as 20 yards.

When seen in 1961-62 the condition of the crop varied from complete check, with spruce and pine averaging about 4 feet in height, to good growth.

One small plot of spruce had reached a top height of 37 feet at 21 years. In the checked areas the trees were chlorotic with very sparse foliage and many were dead although it seems likely that the final cause of death in many cases has been late frost. Spruce rooting in the checked areas was confined to the surface 3 inches. The ground

* Research Officer, Forestry Division, Department of Lands, Dublin.

vegetation was mainly sweet vernal grass (*Anthoxanthum odoratum* L.) and Yorkshire fog (*Holcis lanatus* L.) with herbs, devil's bit (*Succisa pratensis* Moench) and plaintain (*Plantago lanceolata* L.). *Phragmites communis* Trin grew in the drainage ditches.

One of the most striking features of the site at this time was the presence of ground fissures up to about 9 inches wide and 2 feet deep. These, and the dry crumbly condition of the surface peat, immediately suggested that the trouble was due to soil moisture deficiency. The appearance of the trees, however, was such that a nutrient deficiency could not be ruled out. The symptoms here were rather similar to those corrected by potassium applications in Northern New York (Heiberg and White 1951). There was also the possibility that depth to mineral soil might be important. An investigation covering these three possibilities was therefore begun.

METHODS

Since Norway spruce appeared to be most severely affected, and since it would probably be the preferred species on this area, it was chosen for detailed investigation. Twenty plots, each one fortieth acre (11 yards square) were chosen so as to sample the complete range of spruce growth from worst to best. Mean plot height at the end of the 1962 growing season was used as the site indicator in the subsequent investigations.

In the summer of 1963 two samples for gravimetric determination of soil moisture content were taken from each plot. One of these was from 0-3 inches and the other from 3-6 inches. In Spring 1964 two observation wells, 4 inches in diameter and about 40 inches deep were bored in each plot. Mineral soil was reached in 16 of the 40 wells and the depth at which it occurred was noted. Depth to water table in these wells was measured at irregular time intervals. In December 1963 foliage and soil samples were collected. Foliage samples were taken from the current (1963) needles in the upper crowns of the spruces : soil samples were taken to a depth of 6 inches. The samples were sent to the Agricultural Institute's Soil Laboratory at Johnstown Castle, Wexford, where the foliage was analysed for N, P, K, Ca and Mg, and soil for pH and available P, K and Mg.

A further investigation of drainage effect was carried out on a strip 5 feet wide and about 300 yards long. The strip was laid down at right angles to the prevailing drain direction. The height of each tree on the strip, and its distance from the nearest drain, were recorded.

RESULTS

Moisture

The strip described above contained 143 spruces from 6 inches to 15 feet high and from 0 to 62 feet from the nearest drain; and 56 pines from 9 inches to 23 feet high, and from 1 to 63 feet from the nearest drain. In neither species was there any evidence of a relationship between tree height and distance from the nearest drain.

The relationship between mean height of nineteen of the twenty plots and mean moisture content of the top 6 inches of soil is shown in Fig 1 (one of the soil samples was lost). Clearly there is a correlation but it is the reverse of that which would have been expected had tree growth been controlled by moisture content. It appears that much of the variation in moisture content can be accounted for by variation in tree growth. In fact the regression of moisture content on height and (height)^2 shown by the line in Fig. 1, is significant, both in its linear and quadratic components, at the 5% probability level.

There was no significant relationship between tree height and water table level in the observation wells, or with the depth to mineral soil where this was less than about 40 inches from the surface.

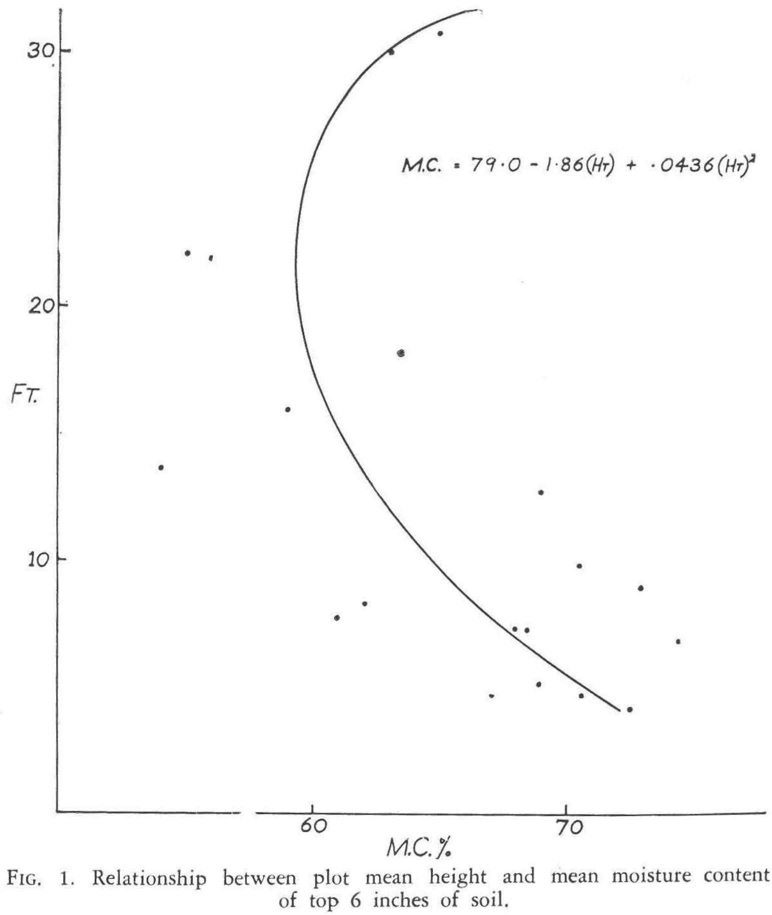

FIG. 1. Relationship between plot mean height and mean moisture content of top 6 inches of soil.

Needle analysis

No significant simple relationship was found between plot height and needle contents of N, P, Ca or Mg. Needle potassium content however showed a strong correlation (Fig. 2). The linear regression of plot height on potassium content of needles is significant at the 0.1% probability level. Multiple regression analysis using N, P and K as determining variables gave the same result.

Soil analysis

Soil pH ranged from 4.4 to 5.4 and was unrelated to tree growth. There was a significant simple relationship between plot height and available magnesium. Multiple regression analysis using available P, K and Mg as determining variables showed that plot height was significantly related to both K and Mg. The nature of this relationship is shown in Fig 3.

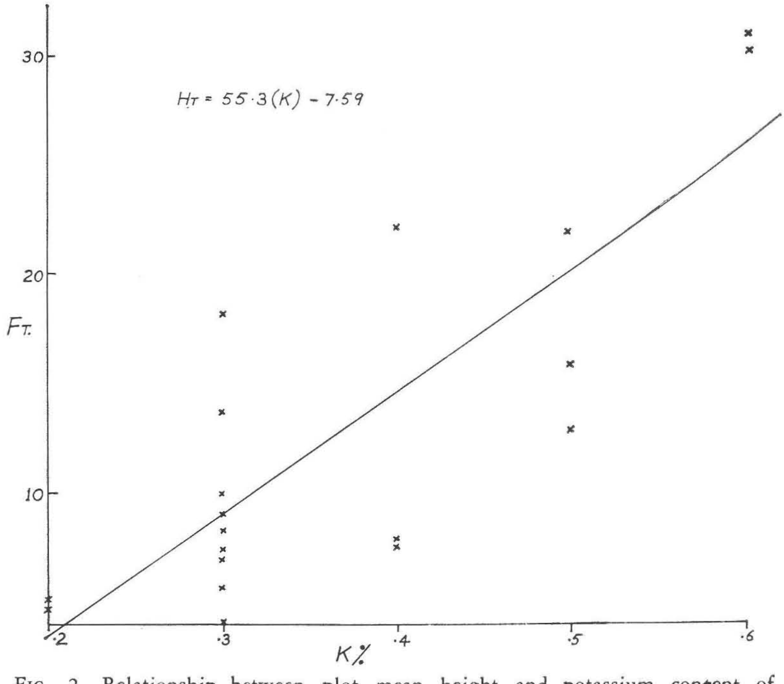

FIG. 2. Relationship between plot mean height and potassium content of needles.

CONFIRMATORY EXPERIMENT

Potassium deficiency was indicated by both needle and soil analyses, and magnesium deficiency by soil analysis only. Since the symptoms more closely resembled those described for potassium than for magnesium deficiency (e.g. Van Goor 1963) an experiment to test the effect of potassium application was laid down early in June 1964. Fifteen of the plots used in the original investigation were extended to one tenth acre for treatment. The best two plots were excluded, since these might be considered to be non-deficient, as were three others which could not be increased in size because of their location. The experimental treatments were 3 cwts. and 6 cwts. per acre of sulphate of potash, with controls. By mid August 1964 there was a striking response in the ground vegetation of treated plots, particularly in the herbaceous plants. (Some of the better plots had closed canopy and had no vegetation). During the growing season there was no visible response in the trees, but this became obvious during the following autumn and winter when control plots reverted to the usual condition for their size category while current needles on the treated plots remained a healthy normal colour throughout. Quantitative effects on growth and nutrient content of needles are being recorded.

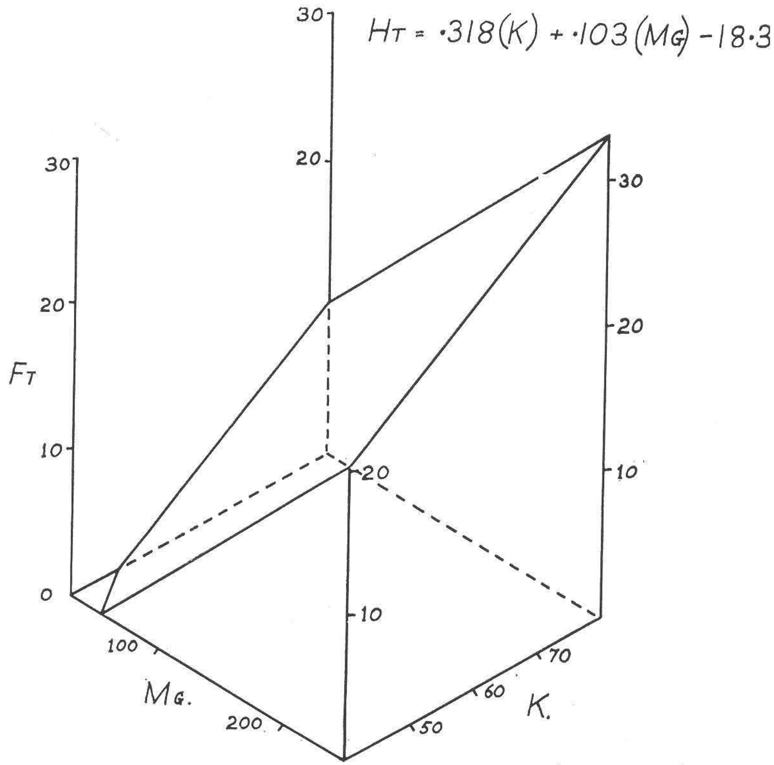

FIG. 3. Relationship between plot mean height (vertical scale) and available potassium and magnesium (horizontal scales).

Because of the indication from soil analysis that magnesium deficiency might be involved, a single 0.1 acre plot was treated with magnesium sulphate at 2 cwt. per acre. So far this has had no visible effect.

DISCUSSION

The investigation provided no evidence to support the hypothesis that tree growth on this site was controlled by soil moisture. On the contrary, it appears likely that decreasing moisture content in the more vigorous plots (Fig. 1) is due to increased evapotranspiration. The increase in the most vigorous two plots may be a result of deeper root systems in those plots.

The most unequivocal evidence on the cause of the trouble came from needle analysis which indicated definite potassium deficiency. Application of potassium appeared to correct the condition completely.

Soil analysis at first indicated magnesium deficiency, and only when the relationship of height with available magnesium was removed, was there a significant correlation with available potassium. It should be stated, however, that the soil was extracted and analysed by methods designed for routine analysis for agricultural purposes.

It appears likely that this site has been so degraded by agricultural use that it is now well below its inherent site quality, as defined by Heiberg *et al* (1964) and the effect of fertilizing may therefore be expected to be relatively long lasting.

ACKNOWLEDGEMENTS

This investigation was initiated by Mr. O. V. Mooney, Chief Research Officer, at the request of Mr. M. S. O Fiacháin, then Senior Inspector, Management. Chemical analysis of soil and foliage were carried out by the Agricultural Institute's Soil Laboratory, Johnstown Castle, Wexford. Much of the field work was carried out by Mr. Eric Joyce, Research Forester.

LITERATURE CITED

Goor, C. P. van, 1963. (Fertilization of conifer plantations). *Ned. Bosb. Tijdschr,* **35**: 129-142 (Trans. Minister of Agr. N. Ireland. No. 34).

Heiberg, S. O., and White, D. P., 1951. Potassium deficiency of reforested pine and spruce stands in Northern New York. *Soil Sci. Soc. Amer. Proc.* **15**: 369-376.

————, Madgwick, H. A. L., and Leaf, A. L., 1964. Some long-term effects of fertilization on old red pine plantations. *For. Sci.* **10**: 17-23.