12. ROOT GROWTH AND ITS RELATION TO THE WATER ECONOMY OF A SITKA SPRUCE PLANTATION

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In the UK, most of the plantation forests have been established in the uplands of the north and west, where the annual excess of precipitation (rainfall) over evaporation has typically led to the development of acid peat deposits which remain wet and waterlogged for most of the year. Because of waterlogging in the rooting zone and/or intense root and shoot competition from other plants (the native ground vegetation), the early methods of direct transplanting of young trees into wet peat were found to require modification if poor growth and crop failures were to be averted (Zehetmayr, 1954). Thereafter, different ploughing techniques have been used where single or double mouldboard ploughs throw up, and invert, ribbons of peat, normally aligned downslope, so that parallel strips are spaced 1.5-2.0 m apart. As a result, a structure (planting unit) of shallow ditches and raised ridges is produced with the inverted turf sandwiched between undisturbed and inverted peat (Figure 29). This structure helps regulate water movement, increase soil aeration and decrease competition from the ground vegetation (Taylor, 1970). At intervals, the shallow ditches are linked to deeper cross drains.

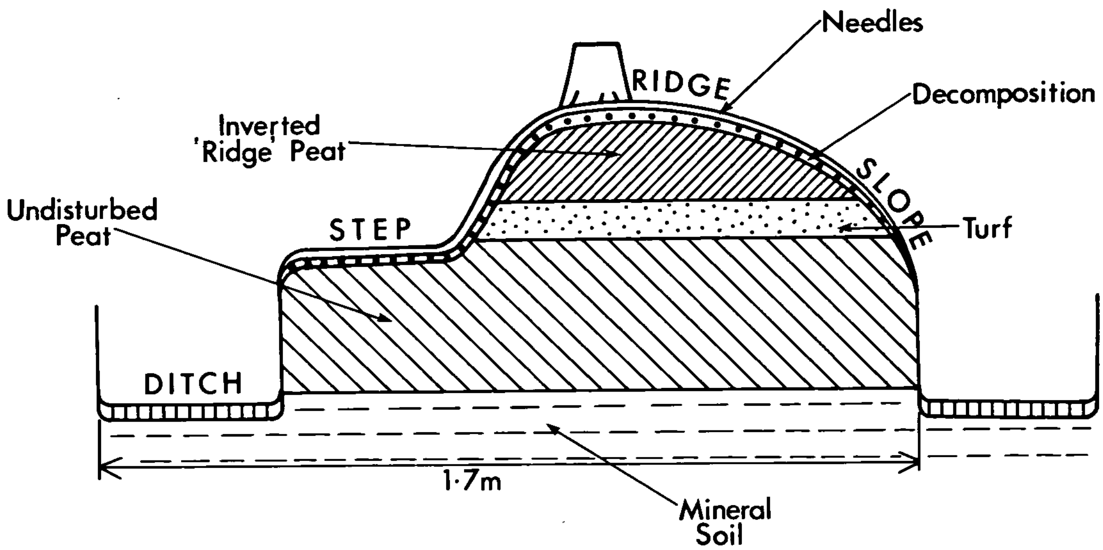
To complement other aspects of a programme concerned with effects of the physical environment on the growth of a young plantation of Sitka spruce, *Picea sitchensis* (Bong.) Car., growing on a peaty gley soil in south Scotland, observations were made of root distribution and growth. Essentially, the provision of water and mineral nutrients is a function of 'fine' roots, whereas the mechanical functions of anchorage and support (for the trunk and canopy) are associated with large coarser roots. To investigate the changing populations and distributions of systems of fine roots, soil cores were taken at weekly intervals, from May until September, using stratified random samples, ensuring that on each occasion 4 cores were removed from the ditch, step, ridge and slope sections of a planting unit at each of 3 locations, (i) within 0.2 m of planting position, (ii) midway between planting positions and (iii) intermediate between (i) and (ii) (Figure 29). To be able to assess the dynamics of fine roots in terms of root lengths per unit volume of soil, a possibly more critical index than estimates of root weight, considerable care was taken when sorting the cores.

1. Occurrence of roots

The detailed study of the spatial distribution of fine roots $<$ 1.0 mm (diameter) shows that (i) most growth occurred from mid-June to late July and (ii) changes in root lengths and weights cm^{-3} of soil were not synchronous, the former usually following the latter. In mid-July, increases in root length were occurring when weights cm^{-3} of soil were decreasing (Figure 30). Concentrations of fine roots were substantially larger in freshly-fallen needles, decomposing ground vegetation and the layer of inverted turf than in undisturbed peat, with roots being absent from many of the samples taken from undisturbed mineral soil. Of the total length of fine roots, 70% was found in horizons at, or above, the original ground level, with 75% of these being confined to ridge sections where concentrations of available mineral elements were maximal. Along rows, fine roots tended to be concentrated close to the trunks of trees, particularly downslope, with fewest per unit volume of soil midway between trees. At right angles to the line of planting, the largest concentrations of fine roots occurred in the ridges and slope sections adjacent to trees, with fewer in the step region and least in the ditches (Figure 29). These patterns of root distribution probably reflect the interplay between differing (i) soil conditions and (ii) distances from the bases of parent trees. Preliminary observations of soil moisture distribution suggest that amounts of rain reaching the forest floor were spatially variable and that rewetting of soil was often restricted to surface horizons during summer. From these and other observations, it was suggested that prolific surface rooting could be attributed to the effects of the relatively abundant supply of mineral elements in surface horizons which became available by mass flow as a result of frequent re-wetting (Ford & Deans, 1977).

On examining the partitioning of rain (precipitation) falling on a forest into stemflow and throughfall, not overlooking the amounts lost by evaporation after being intercepted, it was found that amounts of throughfall reaching the forest floor were largest per unit area near the bases of trees and least near ditches where canopy foliage was densest (Ford & Deans, 1978). Throughfall accounted for 60% of the moisture reaching the forest floor during the summer, stemflow accounting for the remainder and adding to the already relatively large amounts of moisture, attributed to throughfall, near stem bases. Thus, the spatial pattern of fine root distribution mirrors that of moisture, a relation prompting an investigation of the influence of soil moisture on the dynamics of fine roots. Samples were taken from areas (25 x 25 cm) of densely rooted ridge sections, 20-45 cm downslope from the nearest tree. Five cores were extracted to a depth of *c* 50 cm on 20 occasions at 5-day intervals from 3 May to 6 August 1976. Using an improved version of a root measuring device described by Rowse and Phillips (1974), it was found that populations of

A/SECTION THROUGH RIDGE (PLANTING UNIT)



B/GROUND PLAN

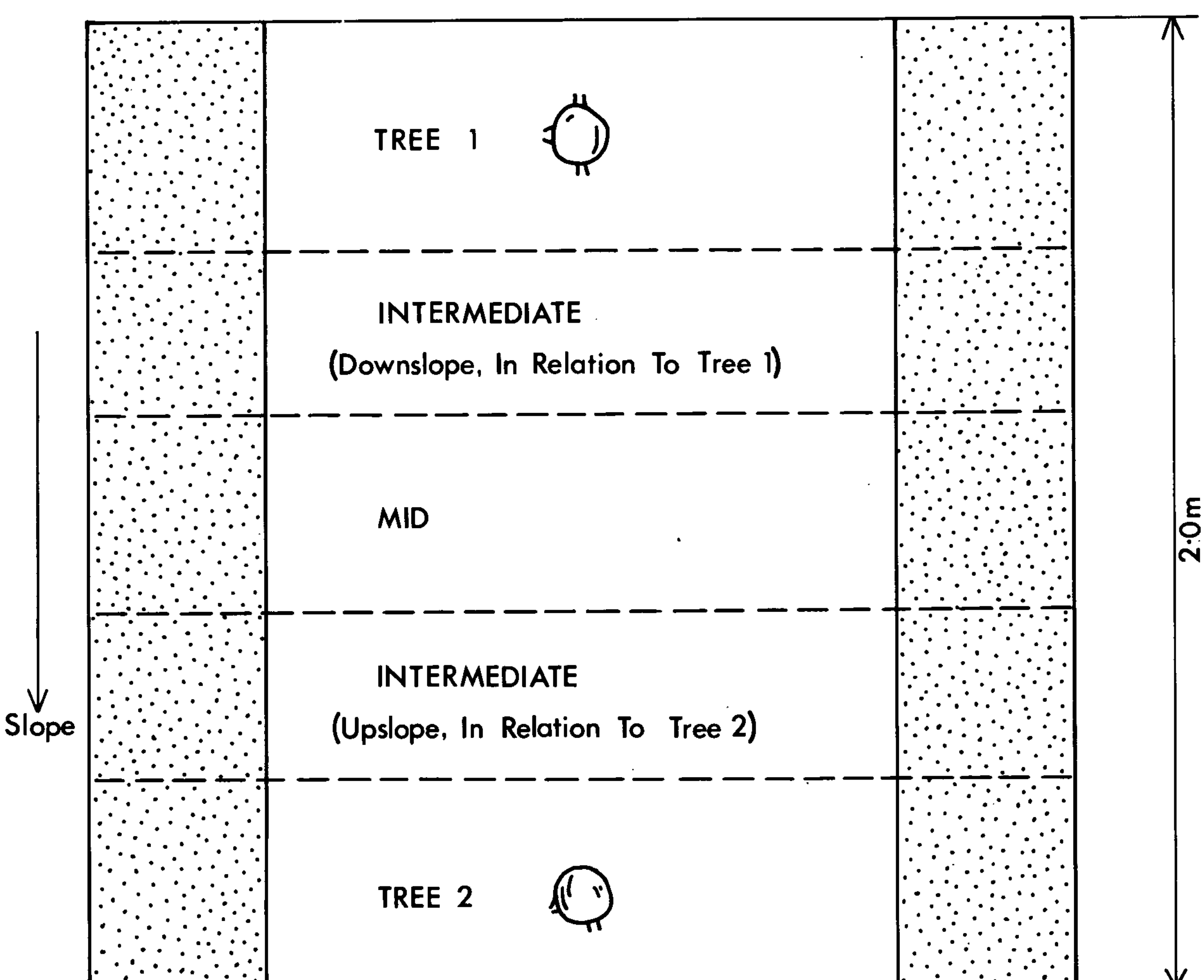


Fig. 29 *Diagrams illustrating A. section through a ridge showing the arrangement of disturbed and undisturbed horizons when planting Sitka spruce and B. ground plan with zones from which stratified-random soil cores were taken at weekly intervals.*

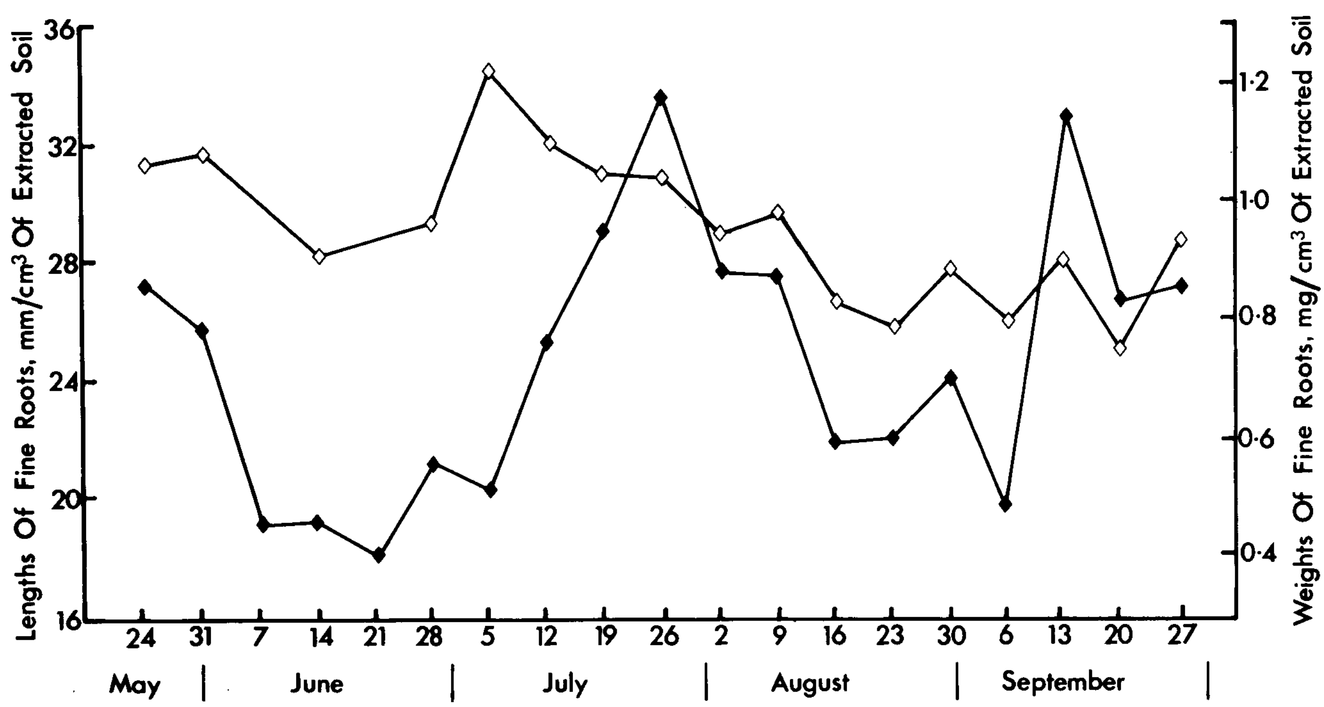


Fig.30 *Seasonally changing weights (◇) and lengths (♦) of fine roots in a plantation of Sitka spruce, 11 years old. (Roots assessed per cm³ of soil).*

fine roots increased in concert with soil temperatures from May to early June, a period of persistent heavy rainfall when soil moisture tensions were very small (close to saturation) (Figure 31). Thereafter, amounts of roots slightly decreased to a quantity that was sustained until late June, a period including the major phase of shoot extension when roots and shoots were competing for probably limited resources. From late June onwards, root populations were significantly and negatively correlated with soil moisture tensions, suggesting that there was insufficient moisture available to sustain root growth even though soil temperatures were favourable. With other results (Deans, 1979), these data indicate that densely planted forests are capable of transforming moist sites into sites of moisture deficit within 14 years of planting, and in so doing possibly adversely affect the functioning of fine roots which, in drier conditions, may be less able to facilitate the uptake of mineral nutrients. In coming to this tentative conclusion, caution is required because little is known about (i) the distribution and functioning of thick roots relative to that of fine roots, (ii) the effects of differing moisture tensions on nutrient uptake and hence tree performance and (iii) the effects of tree canopies of different sizes and configurations on the partitioning of rainfall.

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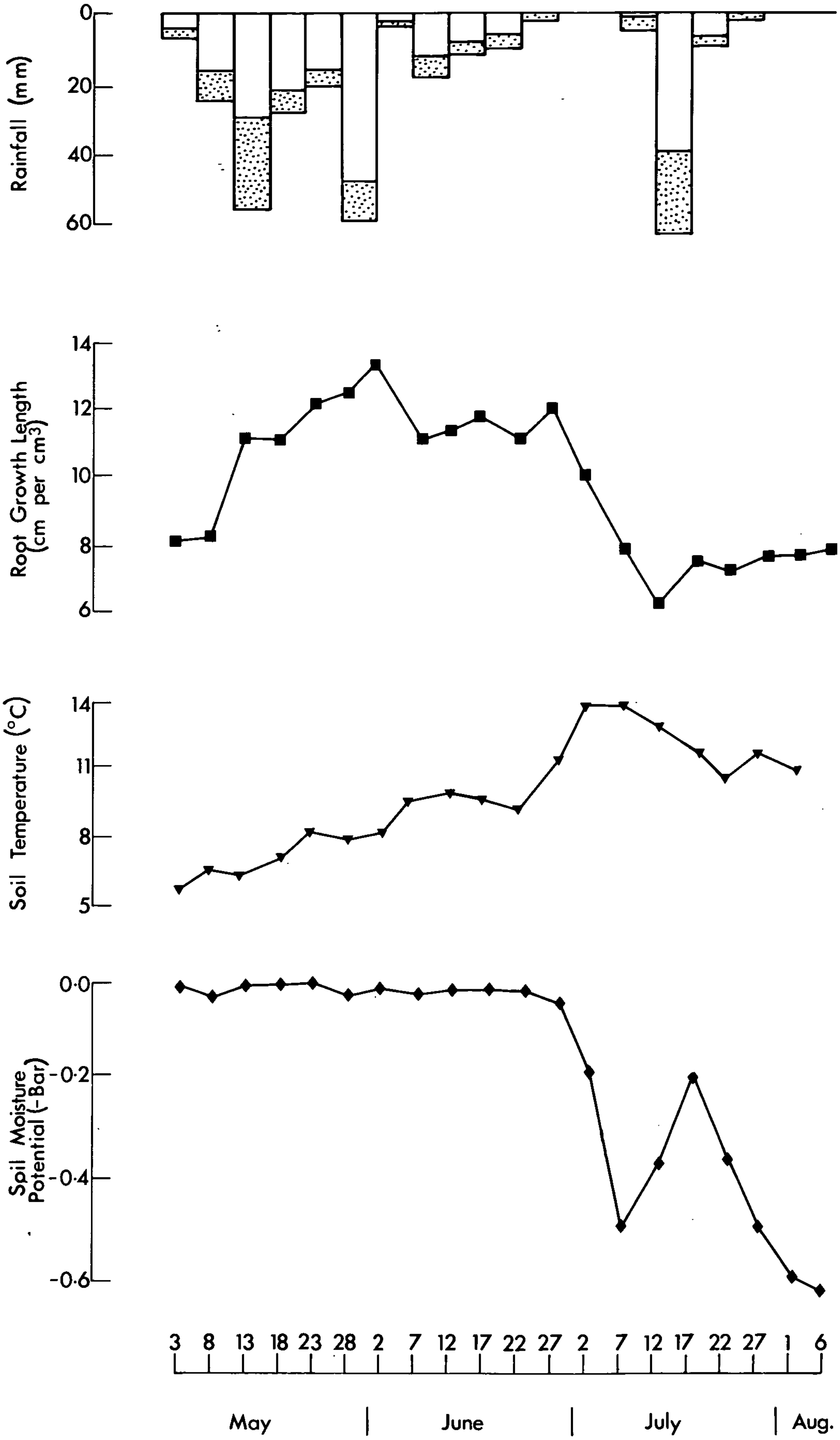

Fig.31 *Relation between the root growth of Sitka spruce, in the inverted turf horizon (see Figure 29), and 2 environmental factors at the same location affecting a plantation 14 years old. The stippled proportions of rainfall indicate rainfall intercepted by, and evaporated from, the canopy.*