Ford, E.D.. 1981 Changes in the growth and structure of a young plantation forest. In: Last, F.T.; Gardiner, A.S., (eds.) *Forest and woodland ecology: an account of research being done in ITE.* Cambridge, NERC/Institute of Terrestrial Ecology, 29-31. (ITE Symposium, 8).

6. CHANGES IN THE GROWTH AND STRUCTURE OF A YOUNG PLANTATION FOREST

E.D. FORD

Whilst it may seem obvious that weather has a strong influence on tree growth—indeed the whole science of dendrochronology is based on this assumption—it has sometimes been observed that trees of the same species in a region may not respond in the same way to variations in weather. This difference in response can be due to differences in physiology between young and old individuals, but the microclimates in which individuals are found are perhaps the major factors. As a forest grows its microclimate changes, for example the amount of foliage increases, so that a larger proportion of rainfall is intercepted and evaporates directly back to the atmosphere without ever reaching the soil.

The structure of a forest determines its microclimate, which, in turn, regulates the amount of growth which is made by trees. Changes in both the growth rate and the structure of a young plantation of Sitka spruce *(Picea sitchensis)* were studied by measuring numbers, lengths and positions of all branches which had been formed on trees 12 years old.

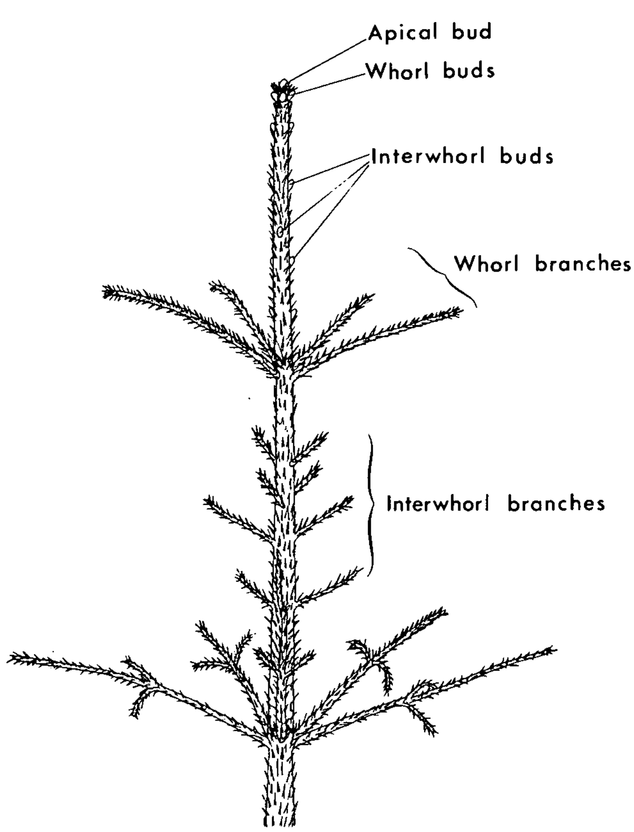

Fig. 12 *The branching structure of the terminal section of* Picea sitchensis.

Each Sitka spruce bud elongates in the spring to form a shoot on which a further set of buds develops to elongate in the following year. There are 3 types of bud: the apical bud which continues growth along the main axis of the shoot, whorl buds occurring in a cluster round the shoot below the apex, and interwhorl buds distributed singly or in small clusters along the length of the shoot. These arrays of buds are found on the main leader of each tree and vigorously growing side branches—particularly those near the top of the canopy. For branches growing further down the tree, there is a tendency first to produce fewer or no interwhorl buds, then not to produce whorl buds, until, finally, the apical bud does not form and the branch dies (Figure 12).

A scaffold was erected in a 12 year old commercial plantation of Sitka spruce, in Greskine Forest near Moffat, Scotland. A single set of measurements was made of (i) the length, (ii) angle from the horizontal and (iii) direction (compass bearing) on (a) every branch on the main stem of each of 10 trees and (b) each shoot on whorl—and interwhorl—branches representative of those at different levels within the plantation (Cochrane & Ford, 1978). Because few branches had been lost from the canopy of age 12, it was possible to obtain a comprehensive historical record of branch growth. Measurements of shoot growth and branch numbers produced from the main stem were continued for 5 years.

The annual height increment of the main shoot (the leader or leading shoot) increased gradually between years 1 and 6, rapidly between years 7 and 10, and fluctuated about an annual mean of 0.8 m in years 11-16 (Figure 13). The number of whorl buds produced at the top of the tree decreased after year 6 from around 12 to 6, and continued at that level with only minor annual variations. Two aspects of branch dispersion were assessed—(i) display in relation to the points of the compass, and (ii) angular divergence from the horizontal. Branches were distributed evenly around the main stem irrespective of the number produced. At the tops of trees, whorl branches were produced at an angle 30° above horizontal, whereas interwhorl branches were produced at only 5° above the horizontal. However, with subsequent growth and as branches became heavier and tree trunks thickened, the angles of both whorl and interwhorl branches decreased, ultimately dropping below the horizontal.

Patterns of branch extension were particularly complex. Until year 10, the growth of whorl branches seemed directly related to numbers of whorl branches which had formed. The more whorl branches the less the mean branch growth and also the less the amount of leader growth; an

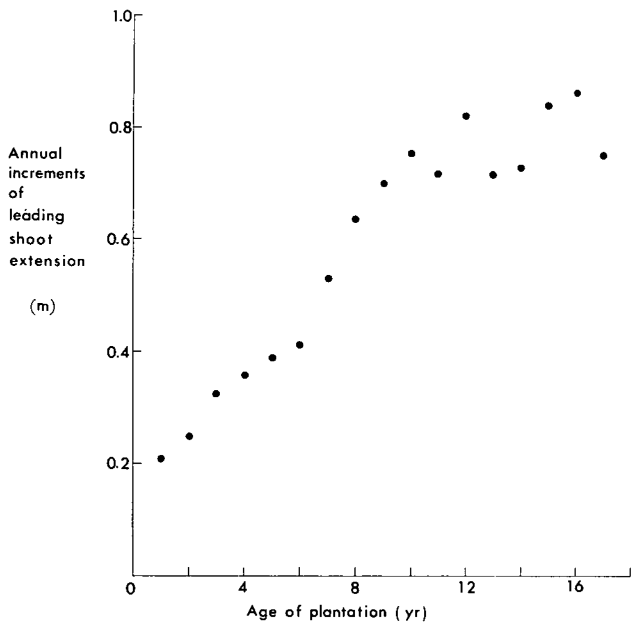

Fig. 13 *Annual growth increments of leading shoots in an ageing plantation of* Picea sitchensis.

indication that growth was determined by within-tree competition for limiting resources. After year 10, whorl branch extension from the main stem was positively related to tree height and leader extension. At this stage, growth of branches seemed to be limited by competition between trees. Interwhorl branches always extended substantially less than whorl branches; their growth was not affected by the different phases of within-tree and between-tree competition.

The critical changes in leader growth and branch production and extension, at 6/7 yr and 10/11 yr, correspond with "canopy overlap" when branches of neighbouring trees touch for the first time and "crown interlock" when branches begin to die (Figure 14). Although detailed analyses of environmental variations at these two break-points have not been made, it is suggested that, from year 7 onwards, with the establishment of a complete canopy cover, there was a marked decrease in amounts of rain reaching what was initially a very wet soil. This decrease could have increased mean soil temperatures and accelerated the mineralisation of the 'grass' cover sward, inverted during site preparation, so stimulating tree growth.

The onset of between-tree competition, as suggested by the stabilisation of mean height increment and the altered relation of branch numbers with branch extension, 10/11 yr after planting, is of particular significance as, after this time, large trees have larger relative growth rates than smaller trees. The death of branches and the maintenance of a constant amount of needles for the crop as a whole suggests that there was competition for light. This suggestion is supported by the restricted growth rates of lower branches and the development of asymetric crowns where trees were touching (Ford & Deans, 1978). In addition to competition for light, there is also evidence to suggest that the potential transpiration demand of trees 10/11 years old is in balance with the amount of water received at the soil surface during the summer months (Milne, 1979). Amounts of

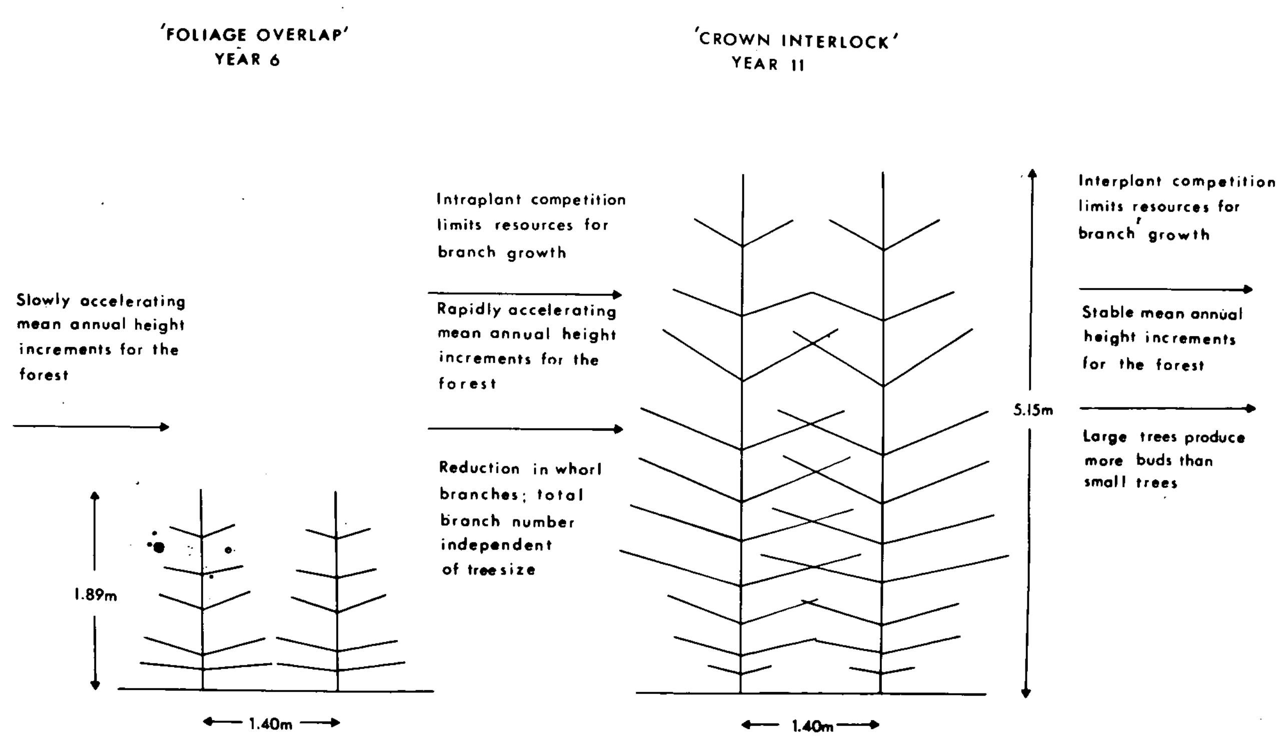

Fig. 14 *The characteristics of branch production and extension described in relation to 2 critical stages in the development of the canopy structure of a young plantation of* Picea sitchensis.

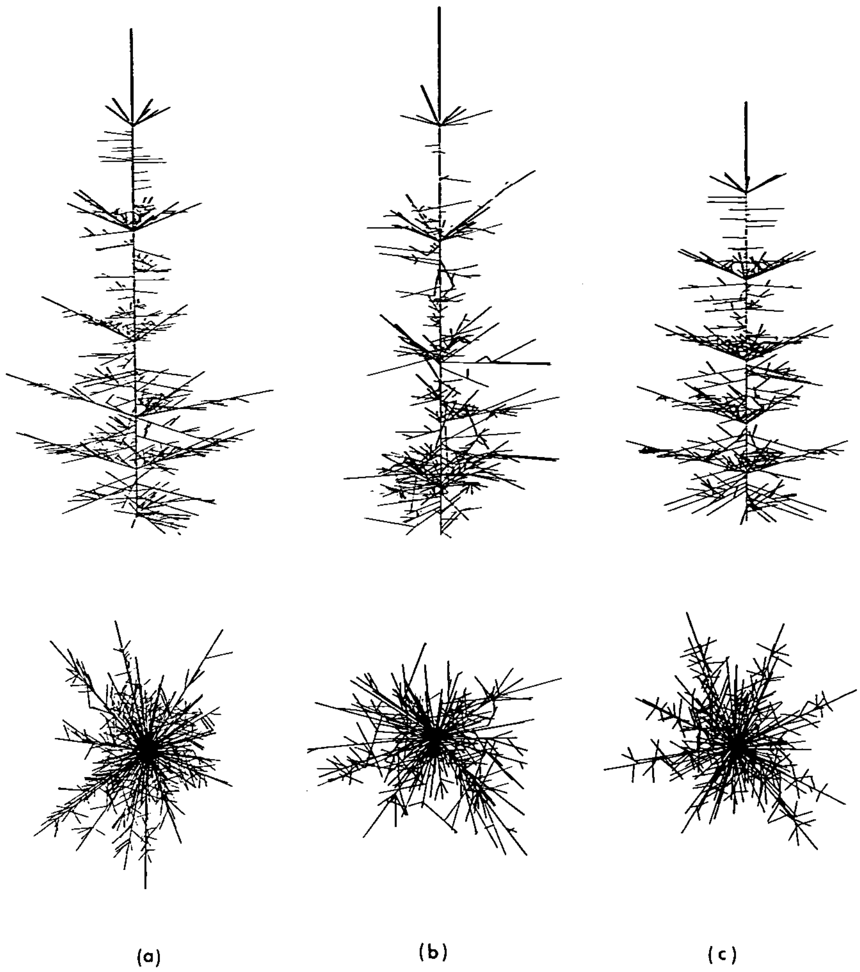

Fig. 15 *Tree structure, in elevation, and plan projections, produced from a model of branch growth with: (a) the variance of the branching rules, as calculated for a Sitka spruce plantation, (b) the variance doubled, (c) variance reduced to zero.*

stemflow in the Greskine plantation are relatively large, possibly because the upper branches are conspicuously upright. They are positively correlated with crown size (Ford & Deans, 1978) and contribute a major part of the water used in the transpiration stream. Large trees may not only intercept more radiation but may also have access to more of the water available for uptake.

The inter-relationships between bud production, dispersion and elongation were studied with sufficient accuracy for them to be expressed in a series of mathematical relationships—each with a calculated variance. These relationships have been used in a computer model so that the growth of a young tree can be simulated. In the first instance, this model has been used to examine just how regular is tree form. If, on the other hand, the variance associated with each relationship is reduced to zero, the tree appears less like a Sitka spruce and, in some respects, more like a fir. If the variance is increased to greater than that measured, then the tree loses its form (Figure 15). Further uses for this model might include the assessment of the effect of reducing whorl branch number, which is at least partially under genetic control, and the effect of this reduction on total branch length. If numbers of whorl branches were decreased, then numbers of knots appearing in the timber would also be decreased. This would be a valuable achievement, but the reduction in the number of branches would also decrease the photosynthesizing area of the tree and limit potential growth.

References

Cochrane, L.A. & Ford, E.D. 1978. Growth of a Sitka spruce plantation: analysis and stochastic description of the development of the branching structure. *J. appl. Ecol.,* **15,** 227-244.

Ford, E.D. & Deans, J.D. 1978. The effects of canopy structure on stemflow, throughfall and interception loss in a young Sitka spruce plantation. *J. appl. Ecol.,* **15,** 905-917.

Milne, R. 1979. Water loss and canopy resistance of a young Sitka spruce plantation. *Boundary-Layer Meteorol.,* **16,** 67-81.