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Editorial

THE SPIRIT OF MEMBERSHIP

WE had long been under the impression that the readership of this journal was of a similar order to that generally attributed to the average scientific paper, that is, two, the author and one other, and are but slightly encouraged by the response to our questionnaire, reported on page 00; encouraged, because so many members took the trouble to reply to the questionnaire, and because among those who replied there were none who indicated that we were totally wasting our time; but no more than slightly, because the number of respondents formed less than one-tenth of our membership. Where are the nine?

We have commented before on the habit of passive membership, members whose purpose is to receive rather than contribute. Societies like this one do not run themselves, they require the devotion of considerable personal time, which might quite easily be devoted to more congenial pursuits. Nor is a journal such as this produced out of thin air, nor does it edit itself. Members are now quite active in attending study tours and midweek day tours, and that is a good thing, it is mainly why the society is there. And in recent years there has been a welcome upswing in the numbers voting in elections to Council. But when it comes to *doing* something, from undertaking the work of an Office in the Society, down to spending a short time filling in a questionnaire, we appear to be very reluctant to become involved.

The Society may survive with such a spirit among its members, but it will not thrive.

The Oceanic Forest[1]

DENIS GRATTAN MOORE[2]

YOU have invited me to talk to you tonight about the oceanic forest—the concept, its execution and the pattern of the forests of the future in our islands.

Let me start by making perfectly clear the basic principle of the oceanic forest. The principle is this:

Every tree selected to grow on to the final crop shall be enabled to develop its full potential growth throughout the rotation of the forest.

There is one vital corollary to this principle. The oceanic forest must be inherently stable.

This principle and its corollary are fundamental to the oceanic system. They are radically different from the German ideas and ideals of traditional forestry upon which British and Irish practice is based. The more you think about it, the more revolutionary it will appear for it affects every forest operation from the selection of parent stock to the final clear fall of the forest itself.

Introduction

On the 16th September 1961 Hurricane Debbie struck Ireland, and its tail ploughed into Argyll and the Western Isles the following night. In Ireland sixteen people were killed and much of the productive forest over 40 feet in height went down. At my own home in County Tyrone it was impossible to get out by road until we had been released by explosives and chainsaws.

For me this was the moment of truth. I realised that day that it is impossible to grow profitable commercial conifer forests in our islands by traditional methods of silviculture for the simple reason that before the forest becomes financially rewarding it will have become unstable.

In the years following the hurricane the clearing up process went on and I had the opportunity to observe about me on private estates and in government forests not only the scale of devastation but also with the keenest interest to see and ponder on the nature of the trees which had escaped destruction. It was about this time that I met the forester instructor at our Northern Ireland training school, Basil Wilson, without whose continual advice, originality of thought and wide experience, the oceanic system would never have come to life.

1. Addresses given to the Society of Irish Foresters, Dublin, on 13th Feb. 1976.
2. Mountfield Lodge, Mountfield, Omagh, Co. Tyrone.

We considered in every possible case why certain trees or stands—concentrating on sitka spruce—had survived. They were usually vigorous trees; they were often in mixed stands where the sitka dominated; but they had two things in common—they had deep crowns—that is their centres of pressure were low; and in every case these deep crowned trees had developed correspondingly strong, wide and firm root systems. To go back to our corollary—they possessed the ingredients of inherent stability. This was the origin of the concept of the oceanic forest.

There are also certain vital requirements from the commercial aspect which are more important than ever before. The timber crop must be as valuable as possible while the rotation is as short as possible. We have set out to devise a sound scientific silvicultural practice which will give the best timber we can grow with the greatest depth and surface area of crown on the trees individually and on the forest as a whole. We are confident that this is the way to obtain the maximum financial return from our forests, and to ensure that the whole of our investment will not be at risk by windblow. As is so often the case in nature, that which is most efficient is also the most aesthetically pleasing. The oceanic forest is beautiful as well as profitable.

This lecture falls naturally into two parts: First—The origins of our forest philosophy—the reason that Britain adopted traditional continental practices, despite our different climate, different species and quite different rates of growth. Second—The Oceanic theory of forestry. A description of the silvicultural methods we have evolved to suit our forests to the oceanic climate in which they grow; to protect them from the hazards as well as to reap the rewards of life on the shores of the Atlantic ocean.

Historical

Botanically speaking, it would be true to say that our era, as far as the islands of Britain are concerned, begins with the bare earth and rock which was left behind as the ice retreated after the last glaciation. Geologically this is a very short span of time—no more than 12,000 years. The descent of the ice cap historically divides us in our day from all that went before. By means of pollen analysis we claim a true record of the sequence in which the land was recolonised with vegetation. The lichens and mosses were followed by the grasses and shrubs, the birches, the alders, the willows and junipers. We know how the pine and oak forests gradually spread over the country, but how remarkable by their absence were the firs, the spruces and the larches among the conifers and the wide range of continental hardwoods which today we look upon as though they were truly indigenous to our islands. We know well the climatic cycle in which our vegetation flourished, and the timings of the changes which, coinciding with the first great clearances by man, gradually transformed our well-wooded countrysides into the barren mountains which are today accepted as the traditional landscape for most of the uplands of Britain and Ireland.

Lying as do the British Islands at the western extremity of the Eurasian land mass, it is useful first to compare and contrast our circumstances with those of the western seaboard of the North American continent, being the only other territory similarly situated in the northern hemisphere and, as we all know well, the home from which the majority of our forest trees originate. As the ice disappeared and the time came for the recolonisation of Britain, its new plant life had of necessity to move northwards and westwards, that is in a direction contrary to the prevailing winds. Furthermore the species themselves were continental in their origin and their inherited characteristics. It was therefore necessary for them not only to swim against the current as it were, but at the same time to adapt themselves to the very different climatic conditions to be found on the stormy and sunless Atlantic fringe. So it was, as we know, that while the various indigenous continental coniferous species of Eurasia were able to move northward behind the retreating ice, few succeeded in crossing the narrow waters westward to Britain. Thus, apart from Scots pine, and the insignificant family of junipers, the gymnosperms had to wait for the conscious efforts of man to re-establish themselves in our islands.

Throughout the early history of the British people there were adequate supplies of timber for the needs of the sparse population. The requirements were for structural uses and for fuel, and later on there were large demands for the production of charcoal. The first significant establishment of man-made conifer forest took place in the middle of the 18th century at the hands of the Dukes of Atholl in Scotland and were of larch. Although Norway spruce had been introduced two centuries earlier, no spruce forests had been planted. By this time the mercantile fleets of British ships were bringing in to our ports exotic timbers of a quality and in a quantity which satisfied the needs of our craftsmen and structural engineers and, moreover, more cheaply than could possibly have been grown in Britain. On the mainland of Europe, however, demands could not be met by seaborne transport and a forest industry evolved suited to the climate, the tools and the needs of a continental environment. Without going into detail, the requirement in Europe for the man-made coniferous forests was for light poles of high form factor suited to growth on the often steep hillsides, to tushing by horse and conversion by the village sawyer. The need for the heavier structural timbers was met by hardwoods.

Thus over the centuries the continental conifer forest and its associated industries developed in a form exactly suited to its climate, its terrain and the utilisation of its produce. The character of the forests themselves has become familiar to every student of forestry, and indeed to every traveller on the mainland of Europe, and is accepted as the classical standard of good management. We shall return to this presently.

The steps which led to the development of coniferous forest in Britain were entirely different. As we have seen, there had been no demand for home grown softwood timber but there had arisen in the colonial empire a need for skilled advice on the management of vast equatorial forest regions across the world. A school for the training of these forest advisers had eventually been set up at Coopers Hill, and a distinguished German forester Wilhelm Schlich from the Indian forest service was appointed as its principal. To cut a long story short, in 1906 the first faculty of forestry at a British university was inaugurated at Oxford with Schlich as its first professor. Sir William Schlich, knighted in 1909, found himself recognised as the leading forester of his time and his published works became the bible of early 20th century silviculture. It is worth remembering however that Schlich had no first hand knowledge of sitka forest, and indeed very little experience of conifer forest in oceanic conditions

Schlich's books are the epitome of classical German forest philosophy and technique. When in the aftermath of the First World War the Government decided to form the Forestry Commission, it was to Oxford and Schlich's Germanic tradition that Lord Robinson (the Commission's first chairman) looked for the staff and the advice so urgently needed to launch the new national enterprise. But the strategic demand for the production of pit props as an insurance for our power supplies from coal, free from the threat of blockade, demanded a growth rate which could not be met by any continental species. Sitka spruce alone could meet the challenge. For this reason the initial plantings of the Forestry Commission, above all the Kielder Forest, were of Sitka spruce designed to grow the narrow continental poles which the nation must have for the mines. And for this reason also the Germanic continental forestry philosophy became, and has ever since remained, the accepted background of the Forestry Commission. But (and here is an astonishing fact) the principal species chosen by the Commission had been Sitka spruce, an oceanic tree from the distant Pacific shore of North America. And here in our wild and wet Atlantic seaboard this oceanic tree was introduced and treated exactly as if it were

Norway spruce growing in the heartland of Europe. There were no major trials; there was no experiment. As long as the produce of the new forests was mining timber, it mattered little. However, the demand today is not for pit props but for the whole range of utilisation from structural timber to pulping material. The produce of conventional silviculture is inappropriate to that demand.

I said at the beginning that this talk fell into two parts. In concluding the first part I want to look for a moment at Sitka spruce, the species, its origins and its characteristics. In the study of this tree must lie the solution to the problems of management which confront us all as we seek to found a flourishing forest industry for the 21st century.

Sitka spruce

I have not been able to trace the whole fascinating story of Sitka. What we know is of great interest but leaves vitally important questions unanswered. To the best of our belief Sitka survived the last ice age on the coastal margins of California and Oregon—and perhaps Washington also. Exactly what happened on the Queen Charlotte Islands is uncertain, though it is conceivable that some seed, but no trees, might have survived there. Sitka was always and has remained a coastal species. Together with its companions such as Douglas fir and Tsuga, it reafforested the coast in the wake of the ice. It fought for its place in the climax forest and extended its range northward along 2,000 miles of seaboard. Its territorial range, however, is oddly restricted. It seldom thrives more than 40 miles from the sea, and is never entirely at home more than 350 metres above sea level, irrespective of latitude. We cannot here and now digress into these and other unusual attributes of Sitka, but they must form part of our silvicultural studies. Its response to light, for example, in that part of the spectrum which favours its powers of conversion are of prime importance. The full spectrum of uninterrupted sunlight appears to be abhorrent to it.

The object of looking at Sitka in this way is that we should approach the establishment of Sitka forests in Britain with completely open minds as a scientific problem to which we are seeking an optimum solution. It is probable that Sitka evolved south of the ice in a climatic environment more akin to Britain today than to its present home on the Pacific coast. It has adapted itself to the changes in latitude and climate which allowed marked provenance variations to develop. There is, however, no reason to suppose that having selected the best provenance for our purpose we should not by our skill and ingenuity grow Sitka to timber at least as well as it grows in its homeland and very much better than we are growing it in

Britain today. In passing, it is worth remembering that the majority of all the Sitka existing is to be found in Alaska, yet the Alaskan provenances are not suitable for growing in the British Isles.

The Oceanic Forest

And now we come to the concept of the Oceanic Forest itself. It is contained in a principle—a principle which favours the maximum growth of the final crop stems. We are dealing with strictly commercial production of timber. We decide what is the individual tree we want to have, in other words the optimum stem volume for the species. This is derived from the pattern of growth as well as from our handling equipment and from the capacity of the automated sawmills of today and tomorrow. We then estimate how many of these optimum stems can grow on any given area—or, put the other way round, how much space each tree must have to develop the required volume. We then determine the management regime which will produce the crop with the maximum economic efficiency, that is, the method which gives the highest return on the capital employed.

I feel that at this point the clearest explanation of the oceanic theory can be obtained by contrasting the continental and the oceanic systems, the one with the other. In its essentials, the continental system sets out to grow as many trees as possible on any given area. Rotations are long, but there is a prospect of profitable thinnings at regular intervals from about the twentieth year onwards. Crowns are restricted from the moment of closing canopy and the lower branches are progressively shaded out. Crowns are subsequently inadequate to sustain the volume growth of which the forest is capable. Timber is grown slowly with narrow but irregular rings. Centres of pressure and centres of gravity are high, while root activity is impaired, therefore the forest tends to become unstable and liable to windblow from an early age. This method of management gives continuous employment, but it is extravagant of labour.

In contrast to this familiar regime, the oceanic system sets out to follow a principle. That is that every tree selected to grow on to the final crop shall be enabled to develop its full potential growth throughout the rotation of the forest. Selection takes place when crowns are still intact. Crowns must thereafter be preserved of sufficient depth to ensure that in those species where this is possible, uniformity of ring width is developed throughout the timber length and throughout the duration of the rotation. Thus the volume increment approximates to the maximum of which the species is capable. This may be referred to as the "rate for the site". The density of the crop on the ground is derived directly from the required timber tree diameter. The length of the rotation is determined by the time taken to attain this diameter. The centre of gravity of the stems and the centre of pressure of the crowns are decisively lower than in the continental method, and root systems are fully developed, resulting in stable, windfirm forest. This method of management entails no labour between the operation of selection and the final clear fall. It is therefore economical of manpower.

The foregoing summary defines the underlying difference between the two concepts. All are familiar with the traditional continental method and great efforts have been applied during five decades to make it work under British conditions. Why and in what respects, therefore, has it failed? It has failed primarily in two ways.

First economically: yields in relation to investment have been inadequate. Another facet of the same defect has been that rotations have been too long to carry the discounted cost of land usage, establishment and maintenance over so many years.

Second silviculturally: the continental system produces a forest which is inherently unstable in our wet and stormy oceanic climate. In other words, a forest which *could* grow fast enough to be profitable will almost certainly become unstable and liable to windthrow before it shows an economic return.

These two simple statements illustrate the weakness of the continental system in Britain. If yields are raised more than marginally in our characteristic environment, our forests will blow down. The reason is clear: in the areas of high rainfall where our most productive forests grow, rooting tends to be shallow. If combined with a high centre of pressure this *must* result in instability.

The economic failure of the continental system may be stated in silvicultural terms thus. In the early stages the traditional crop is too dense. By shading the lower crowns of the strong, the weak deprive their superiors permanently of their vital vigour. As the final crop approaches maturity, there are neither sufficient stems standing, nor is the total area of crown adequate to use the resources of the ground to the full, while the individual crowns are incapable of maintaining the growth potential of each respective tree.

By what conceivable means then can a significantly higher yield be obtained in a windfirm forest? For those interested in the purely technical reasoning behind the oceanic method, the total effective area of crown in relation to the number of stems brought to the final crop in the forest is much greater in the oceanic than in the continental method. Timber is predominantly composed of carbon. Since this carbon is wholly obtained from carbon dioxide in the air through the stomata of the leaf, it is the essence of the oceanic method of silviculture that it can provide that extra area of leaf—and therefore of stomata—which ensures that a much larger volume of timber can be grown on any given site, and above all remain windfirm.

The traditional idea has always been that the conditions which determine the yield of a forest are to be found on the ground and that the limiting factors to the yield of a species in the forest lie in the region of the base of the tree—fertility, soil texture, water, microbiology and the root structure of the tree itself. (How often it is quoted that no more can be taken out of a site than the ground gives.) In fact, the very contrary appears to be the case. The limiting factors to growth of our evergreen conifers are to be found in the crown, and the critical stomatal intake of carbon dioxide. We can influence the area of the base by cultivation, fertilisation, and by preserving the ecology of the forest floor. Here are to be found the vital ingredients of healthy growth, but not the essential constituent required for the process of conversion to timber—carbon, from atmospheric carbon dioxide. Unless the crown carries a large enough leaf area, the all important carbon cannot be absorbed in sufficient quantity to satisfy the ability of the tree as a whole to convert its intake to wood. We may be unable in any significant way to influence the concentration or availability of CO_2 in the atmosphere, but we can decisively influence the capability of the forest to absorb what is present. The oceanic techniques are designed to increase the total leaf surface of the crown of every stem contributing to the final yield by as much as four times that resulting from traditional practice. This is the virtue of the oceanic system.

The Oceanic System in practice

Turning now from theory to practice, we must ask ourselves three questions about the Oceanic System of forestry. Is it (1) Possible; (2) Practicable; (3) Profitable.

To take these in turn.

1. *Is it possible?*

The short answer is of course "yes".

It is possible to select final crop trees early in the rotation and ensure that they are given the opportunity to develop their full growth potential. Whether the ideal "rate for the site" as defined earlier in this lecture can be sustained is important as a target in striving to obtain the maximum yield, but in any case the crop must grow on to attain the planned production. The planned yield I have suggested for Sitka is 750m^3 per hectare. The measure of success is the number of years this will take. The total production from Sitka on a site attaining Y.C. 24 will reach this figure by continental management in 32 years, *but* half of the total will have been squandered in unprofitable thinnings whose production will have damaged the final crop beyond repair.

2. *Is it practicable?*

Can the oceanic system be operated as a normal forestry process, by trained men with an average level of supervision? Again the answer is "yes".

The method we have adopted is practical and effective, but other and better techniques may be evolved in the future. Let us see what is implied in adhering to our principle, taking Sitka as our example. Saw timber fetches the highest prices, so let us consider first the sawmiller's ideal log. It is a stem of breast height diameter of 36 cm running to a 12 cm top, with a volume of three-quarters of a cubic metre. Its green weight will be of the order of 750 kg. This log can be extracted and transported at minimum cost for volume, and is thereafter suitable for fully automated conversion. As far as possible produce from the forest should not exceed these dimensions by more than 15% nor fall below them by more than 20%. This, then, is the required tree which will fetch the top price in the market today, and for as far as it is possible to look into the future. It gives the forester a good all-purpose target, exactly within the capacity of his skills to produce, but leaving little freedom for errors. On an average site this stem can be grown in thirty years without difficulty.

To extract the full return from the site, what then is the maximum number of stems which can be carried on a hectare of forest? Or translated into other terms, how much space does the individual tree in the forest require in order to develop its full potential as defined in the foregoing terms? The answer to the question obviously offers scope for discussion and individual judgment, and during the further evolution of the oceanic system experience may cause estimates to be revised. Observation and measurements in our north western regions suggest that 10 square metres per tree, or 1,000 trees to the hectare, is near the mark. If this be accepted for the time being, let us review the steps which must be taken to attain this result.

(i) *Selection*

The planting stock most suited to our foremost areas of establishment comes from seed of Queen Charlotte Islands origin. Extensive observation reveals that no more than 50% of this stock possesses the vigour to give an economic return in the forest. *Furthermore, that elite* 50% *can only manifest itself in the forest, after planting, on the site where it is destined to grow to maturity.* It must be from this starting point that the design of the new highly productive Sitka forests will spring. No tree must grow to timber unless it belongs to that selected vigorous half of the best stock we can plant. Since some uniformity in spacing of the final crop is desirable, a degree of latitude in choice must be allowed. Thus on every hectare some 2,500 trees must be planted to offer in the region of 1,250 for selection. From these, 1,000 well-placed stems can be chosen. The timing of selection is important. It should be as late as possible having regard both to the discounted cost of the process of selection itself and to facilitating the actual choice of the most vigorous stems. The moment before the closing of canopy is most favourable. If it is left later it is both difficult to see clearly and physically the going may be very hard. If too early, errors in choice may be made and the truncated stumps may prove to be over-competitive.

(ii) *Treatment of Un-Selected Trees*

It is again fundamental to the oceanic process that those stems which are destined to be eliminated should contribute towards, and not detract from, the development of the final crop. To this end much thought and trial have been directed, but further experiment will continue. It is firstly essential to simulate and then to preserve a fully forest environment. The more rapidly the ground is covered the better. Therefore no unwanted tree should be destroyed by the act of culling, but each must in its due time be allowed to die naturally. The whole micro-biological life of the forest floor must conform to the natural processes of death and decay. The abrupt destruction of large numbers of root systems such as is suffered by the action of conventional thinning is highly disruptive of the very mycorrhizal association of fungus and root which we are seeking to encourage. Again, the sudden opening of the forest floor to light causes a faster breakdown of debris, resulting in a denial by bacterial action of readily available nitrogen to the surviving trees.

There may be a variety of treatments which will satisfy all the requirements, and experiment will arrive at the correct solution. One method has proved to be a practical forest operation, comparatively moderate in cost—that of lopping the tops from unwanted trees at between one and two metres above the ground. If it is correctly executed, it is the only silvicultural operation carried out until the forest is felled some twenty odd years later. There is no brashing, no pruning—and therefore no expenditure on maintenance apart from ensuring from time to time that drainage remains in good order.

(iii) *The Rotation and the Yield*

Having specified the stem to be grown and the space that each tree needs in order to obtain the optimum dimensions, the process of selection ensures that the most vigorous trees and they alone grow on for the final crop. Adopting the estimate of 10 square metres as being the average area that every crown must have to obtain sufficient light and air for the production of 0.75m³ of timber, one fully stocked hectare will yield 750m³ at the end of the rotation. Sitka forest will, for example, be classified as a "28 year", a "30 year" or a "35 year" etc. forest, this being the anticipated time to yield, in each instance, the 750m³ which has been stipulated. Existing yield classifications and the associated tables based on statistics of the continental system are not relevant to forest grown by the oceanic method and can be confusing. A calculation of basal areas and current annual increments at the culmination of the oceanic rotation gives results which may seem exaggerated by conventional standards. I ask you to remember that the timber production of the oceanic forest derives from the total crown, and that provided the leaf surface is there, the increments are within the capacity of the species.

3. *Lastly, is the oceanic system profitable?*

Referring to the spruces, it is the object of management to bring the short rotation crop to a volume of some 750m³ to the hectare. There are no returns from thinnings. A high proportion of the final crop is available for the sawmill.

By any means of assessment the oceanic system is very much more profitable than traditional practice. The value of a hectare of 750m³ of Sitka on 1,000 stems at today's prices is about £8,000. Or, if you prefer this expressed in imperial measure, we will expect £1m. return on every 320 acres of fully productive oceanic forest. It is our belief that we can attain this return in thirty or so years.

Conclusion

In conclusion I will bring together in a few sentences the elements which comprise the concept and the execution of oceanic silviculture.

Objective

The aim of the Oceanic System is to grow the maximum volume of the most valuable timber in the shortest possible time, preserving stability throughout the rotation.

The target volume for Sitka spruce is to grow 750m³/hectare. The time taken is a measure of the quality of the site and the skill of management.

The Method

Theory: Decide before operations start what is the optimum stem of timber to be grown in the forest. Observe how much crown space each tree requires to produce this standard stem in conditions of optimum growth. Calculate the maximum number of stems which can be grown to the optimum volume on a given area of ground.

The (mathematical) product of the number of trees multiplied by the average individual volume gives the total standing volume of the crop at rotation.

When this volume is reached, this is the period of maximum financial return and the forest is ready to be felled.

Practice

Establish the crop to ensure a quick and successful get away. As canopy closes, select the "dominants" to the number determined, spacing them as uniformly as can be readily achieved. Eliminate crown competition from the remainder without causing their death.

Leave the forest alone—for twenty years or so. When the planned volume is attained, clear fell.

My last words must repeat the oceanic principle: "Every tree grown to the final crop in the forest shall have developed its full potential growth". The rewards can be rich, and the forest beautiful.

Effects of Fertilizing Moribund Pines on a Granitic Soil in Northern Ireland

D. A. DICKSON[1]

Summary

DATA are presented on the responses of slowly growing 25 year old Scots and Lodgepole pines to fertiliser application. The growth of both species increased quickly and markedly after the application of fertiliser phosphate. The rate of growth increase in Scots pine was slower but longer lasting than in lodgepole pine and growth increased almost linearly up to the highest rate applied (67.5 kg P/ha as triple-superphosphate). In lodgepole pine there was no further increase in growth at rates above 46 kg P per ha applied as superphosphate. Neither N applied as sulphate of ammonia nor K applied as muriate of potash affected the growth of Scots pine but in lodgepole applied N tended to increase and applied K to decrease growth.

There was no growth response in either species to any of six trace-elements applied in addition to a compound N P K ertiliser.

The foliar concentration of all elements determined except P were above the accepted deficiency levels. In the untreated trees foliar P concentrations were low throughout the course of the experiment; applied phosphate significantly increased foliar P concentration but at the lowest rate of application (22.5 kg P/ha as superphosphate) the concentration again approached deficiency level after seven years.

It is concluded that treatment of such crops with phosphate is economically justified. Triple-superphosphate is an effective fertiliser but rock phosphate may be preferable on cost grounds.

1. Introduction

Rostrevor forest lies in the foothills of the Mourne Mountains in the extreme south of Co. Down in Northern Ireland. On the lower slopes growth of a large variety of tree species, including hardwoods and even eucalypts, has been good. On the shallower soils of the upper slopes, however, growth has been disappointing. An inventory in 1963 showed that growth was unsatisfactory on at least 500 ha and it was decided to see if application of either major or minor nutrient

1. Agricultural and Food Chemistry Research Division, Northern Ireland Department of Agriculture, Newforge Lane, Belfast BT9 5PX.

elements would improve growth. Two separate experiments were laid down in April 1963. One was a N×P×K factorial experiment, the other a randomised block experiment involving the application of a range of minor nutrient elements. The test crop was an intimate mixture of Scots pine (*Pinus sylvestris,* Linn.) and lodgepole pine (*P. contorta,* Dougl.) which had been planted in 1938. By 1963 the trees, then 25 years old were only about 1.5 m high.

Little work has been reported on the mineral nutrition of trees growing on granitic soils in the British Isles.

2. Site and Crop Description

The experiments are at an altitude of 250 m O.D. and the site is relatively exposed. Rainfall is about 1,250 mm per annum with an average of 110 'rain-days'. The area has an easterly aspect and the slope is steep (38 %). The soils are derived from glacially deposited Mourne granitic till. They range from a humus-iron podsol to a peaty iron-pan soil depending on the local development of the iron-pan. The B horizon is strongly indurated. An upper peaty horizon varies in depth from 15–46 cm being deeper in depressions between boulders. Tree roots occur down to but do not penetrate the indurated layer. Samples of the peaty horizon and of the mineral A horizon were collected from 12 randomly chosen sites in the experimental area. The organic samples were analysed for total phosphorus and potassium concentration: the 'available' (that fraction soluble in N ammonium acetate adjusted to pH 4.4) concentration of the same elements in the A horizon was also determined. The pH was measured on a 1:2.5 soil: water suspension. Mean values are shown in Table 1.

TABLE 1
Mean concentrations of phosphorus and potassium and pH of organic and upper mineral soil horizons

Factor	Organic Horizon	Mineral 'A' Horizon
pH	3.84	4.17
	mg (total)/100 g D.M.	mg ('available')/100g D.M.
Phosphorus	45	0.17
Potassium	45	6.12

These data indicate that the potassium status of the soil is moderately high by agricultural standards but that both available and total phosphorus concentrations are very low. Soil pH is also low.

The area was planted in 1938, with a 1:2 mixture of Scots pine and lodgepole pine. The Scots pine were from seed collected at Altyre in Scotland. The provenance of the lodgepole is listed simply as 'Canadian' but the trees have all the characteristics of an 'inland' provenance (O'Driscoll, 1968).

The trees were planted directly into the soil. The vegetation was screefed but very little drainage was done at planting and none has been done since. A handful of basic slag was applied per tree at planting.

The vegetation of the unplanted area adjacent to the experiment has been much affected by burning and sheep grazing. *Calluna, Erica cinerea, E. tetralix Trichophorum caespitosum* and depauperate *Molinia caerulea* are the most common species but about 20 per cent of the ground is bare of vegetation. With the exclusion of grazing and burning within the forest, *Molinia* has increased in abundance and vigour; *Calluna* has increased but has not become dominant. *Ulex gallii* is also common in the fenced area of the experiment, but is infrequent outside.

3. Designs and Treatments

3.1 Major Elements (Rostrevor CRD1/63)

The experiment is in the form of a complete N×P×K factorial with two replicates. Square 0.04 ha plots were laid out in 1963. The treatments are listed in Table 2. All fertilisers were broadcast

TABLE 2
Fertiliser Treatments

Treatment	Fertiliser	Rate of application	
		Kg fertiliser/ha	Kg element/ha.
P_1	Superphosphate	250	22.5 P
P_2	Superphosphate	500	46 P
P_3	Triple superphosphate	325	67.5 P
N_0	Nil	—	—
N_1	Sulphate of ammonia	156	33 N
K_0	Nil	—	—
K_1	Muriate of potash	125	63 K

manually in April 1963. One 'reference' plot per block was left untreated, the trees were measured but the data have not been included in any statistical analyses.

The 20 trees of both species nearest the middle of each treated plot were measured at 3-yearly intervals with annual height growth being determined for the intervening years. Samples of foliage were collected for chemical analysis each year from 1965–1973. Standard methods of collection and analyses were used. (See Dickson 1965.)

3.2 Minor Elements (Rostrevor CRD 2/63)

This experiment is in the form of a randomised block with two replicates. The plots were 0.04 ha in area. The treatments applied are shown in Table 3. Since it was thought likely that growth was primarily being limited by one or more of the major nutrient elements a basal treatment of 375 kg per ha of a compound fertiliser (supplying 30 kg/ha N, 40 kg/ha P and 44 kg/ha K) was broadcast over each plot at the same time as the other treatments.

TABLE 3
Treatments

Element	Symbol	Form Applied	Rate of Application (kg/ha)
Zinc	Zn	Zinc chloride	22
Copper	Cu	Copper sulphate	22
Cobalt	Co	Cobalt sulphate	22
Boron	B	Sodium borate (Borax)	11
Magnesium	Mg	Magnesium carbonate (Magnesia)	56
Molybdenum	No	Ammonium molybdate	1.5

All elements, except Mg which was broadcast dry, were applied to the ground in solution via a sprayer.

The trees were measured and foliar samples collected as in previous experiment.

4.1 Effects of Major Elements on Growth and Foliar Nutrient Concentrations

4.1.1 Phosphorus

(a) Annual Height Growth

The effect of applied phosphate on annual growth of both species over the period 1963–1973 is shown in Figure 1. Prior to treatment annual height growth was only about 5 cm and in the untreated trees it has remained so throughout the experiment. Even the lowest rate of applied phosphate more than doubled height growth by the second season after application.

Growth increase was initially more rapid in lodgepole pine. In this species the maximum height growth occurred in the seventh year after fertilizing but thereafter growth in all phosphate treatments decreased. Annual height growth was significantly better in the P_2 treatment than in the P_1 treatment but it was almost the same at the two higher rates of phosphate application. Maximum annual height growth was 44 cm.

The rate of height increase was slower in Scots pine than in lodgepole pine, but it continued to increase for ten years after treatment.

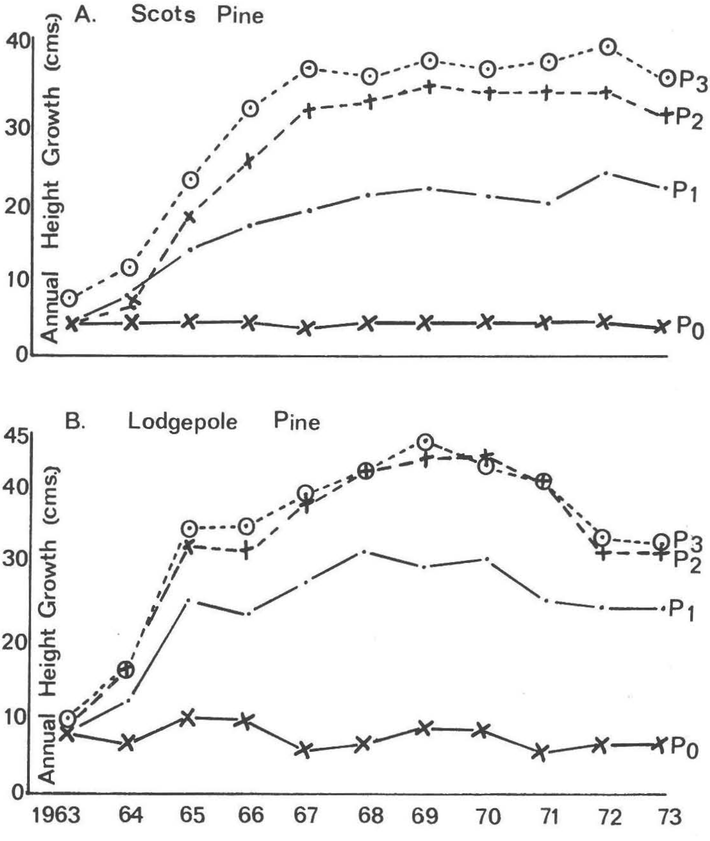

Figure 1: Effect of applied phosphate on annual height growth 1963–73. (Rostrevor C.D.R. 1/63).

After the second season annual leader growth in Scots pine increased progressively with increase in rate of applied phosphate. The maximum annual height growth of 39 cm occurred in the P_3 treatment in the tenth season after treatment.

(b) Mean Height, Top Height and Height Increment

Total height of each tree in the measurement plots was measured at the end of the eleventh growing season after treatment. The effects of applied phosphate on mean height (the arithmetic mean of all measured trees), the mean of the three tallest trees in the measurement plot (corresponding approximately to 'top height' (Hamilton and Christie 1971) and height increment 1963–1973 (the difference between mean height at December 1962 and mean height December 1973) are shown in Table 4.

TABLE 4
Effects of applied phosphate on Mean Height, 'Top Height' and Height Increment

Species	P_0[1]	Phosphate Treatment P_1	P_2	P_3	S.E.m.
		Mean Height Dec. 1973 (m)			
S.P.	2.12	3.74	4.66	5.63	0.26**
L.P.	2.81	5.00	6.02	6.29	0.36 n.s.
		'Top Height' Dec. 1973 (m)			
S.P.	3.22	5.50	6.26	7.02	0.23**
L.P.	4.68	6.30	7.55	7.73	0.35*
		Height Increment 1963–1973 (m)			
S.P.	0.44	1.98	2.94	3.53	0.17***
L.P.	0.72	2.65	3.59	3.55	0.20*

1. 'P_0' data not included in statistical analyses.

Table 4 illustrates that Scots pine is more responsive to rate of applied phosphate than lodgepole pine: the response curve for Scots pine was in all cases almost linear whereas with lodgepole pine a quadratic component was very evident. At the highest rate of applied phosphate height increment in Scots pine was only 2 cm less than in lodgepole pine but at the two lower rates height increment in lodgepole pine was greater than in Scots pine.

In the most effective treatments both species have grown almost 3 m taller than the untreated trees in the eleven years since fertilizing.

(c) Basal Area Growth

The effect of applied phosphate on basal area at the end of the eleventh growing season is shown in Table 5.

TABLE 5
Effect of applied phosphate on Basal Area at Dec. 1973

Phosphate Treatment	B.A./ha (sq. m.)		No. Trees/ha		B.A./tree (sq. m.)		(B.A./ha)	Total No
	S.P.	L.P.	S.P.	L.P.	S.P.	L.P.	(sq. m.)	tree/ha
P_1	3.35	11.60	2,040	2,560	.002	.005	14.95	4,590
P_2	4.85	18.95	1,780	2,410	.003	.008	23.80	4,190
P_3	9.05	16.65	1960	2,090	.005	.008	25.70	4,050
s.e.m.	1.23*	1.20**			.0006*	.0007**		

The greater responsiveness of Scots pine to rate of applied phosphate already illustrated by height data is even more apparent for diameter growth. At the highest rate of applied phosphate the basal area per hectare of Scots pine was almost three times greater than at the lowest rate, whereas in lodgepole pine the maximum increase due to treatment was just over 50 per cent. However the basal area expressed either on a per hectare or per tree basis, was very much higher in lodgepole pine at all levels of applied phosphate. Total crop basal area ranged from 14.95 m^2 (4,590 trees/ha) in the P_1 treatment to 25.70 m^2/ha (4,050 trees/ha) in the P_3 treatment.

(d) Foliar phosphorus concentration

The effects of applied phosphate on foliar P concentrations at the end of four growing seasons are shown in Table 6.

TABLE 6

Effects of applied phosphate on foliar phosphorus concentrations % D.M.

Treatment	Species	1965	1967	1969	1973
P_0*	S.P.	.10	.10	.07	.10
	L.P.	.08	.08	.08	.09
P_1	S.P.	.14	.13	.10	.12
	L.P.	.13	.12	.10	.11
P_2	S.P.	.18	.18	.14	.13
	L.P.	.15	.16	.14	.13
P_3	S.P.	.18	.19	.15	.15
	L.P.	.15	.18	.14	.13
S.E.m. ±	S.P.	.003***	.006***	.004***	.006 n.s.
	L.P.	.004**	.003***	.004***	.005*

* P_0 data not included in statistical analyses.

Except for Scots pine in 1973, applied phosphate significantly increased foliar P concentration. There were big differences in foliar P concentration in both species between the control and the lowest rate of applied phosphate and between this and the two higher rates. In Lodgepole pine there was no difference between the two higher rates except in 1967 but in Scots pine foliar P concentrations were higher in the P_3 treatment in each year except 1965. Neither applied nitrogen nor potash significantly affected foliar P concentration throughout the course of the experiment.

In the untreated plots foliar P concentrations were at or below the deficiency level of 0.10 per cent dry matter suggested by Van Goor (1970) and at the lowest rate of phosphate application both species had reached this value by the seventh season after treatment, although values were again higher in the sleventh season.

4.1.2 Nitrogen and Potassium

(a) Height growth

Neither applied nitrogen nor applied potash significantly affected the height growth of Scots pine. In Lodgepole pine applied nitrogen tended to increase and applied potash to decrease height growth but neither effect was statistically significant for any individual year except 1968 when leader growth was 39.1 cm in the K_0 treatment and 34.4 in the K_1 treatment (S.E.m. ± 1.13).

Both nitrogen and potash significantly affected the growth of lodgepole pine over the three growing seasons 1967–1969 (incl.). This is shown in Table 7.

TABLE 7

Effect of nitrogen and potash on growth of Lodgepole pine 1967–1969 (incl.) (cm)

Treatment	N_0	N_1	P mean			
P_1	83	85	84			
P_2	113	126	119			
P_3	108	132	120			
N mean	101	114	108			
			K mean	P_1	P_2	P_3
K_0	106	121	113	89	127	125
K_1	97	107	102	79	111	116

S.E. N mean $= \pm 3.5$* S.E. K mean $= \pm 3.5$* S.E. P mean $= \pm 4.3$***
S.E. $N \times P$ mean $= \pm 6.1$ n.s.

The overall effect of nitrogen in increasing growth over the three-year period is significant and there is a suggestion that its effect is greater at the higher rates of applied phosphate. The $N \times P$ interaction is, however, not significant. Rate of applied phosphate did not affect the magnitude of the growth decrease due to applied potash.

The effects of applied nitrogen and potash on height increment in both species over the eleven years of the experiment is shown in Table 8.

TABLE 8

Effects of applied nitrogen and potash on height increment 1963–1973 (cm)

	Scots Pine			Lodgepole Pine		
	N_0	N_1	K mean	N_0	N_1	K mean
K_0	2.68	3.10	2.89	3.18	3.44	3.31
K_1	3.00	2.48	2.74	3.11	3.31	3.21
N mean	2.84	2.79		3.14	3.37	

S.E. N or K mean $= \pm 0.13$ n.s. S.E. N or K mean $= \pm 0.17$ n.s.
S.E. $N \times K$ mean $= \pm 0.19$* S.E. $N \times K$ mean $= \pm 0.23$ n.s.

No main effects of applied nitrogen or potash on height increment were significant but the N×K interaction on height increment in Scots pine was significant at the 5% level. Either element on its own increased growth slightly but where both were applied there was a reduction in growth. This did not happen with lodgepole pine.

(b) Foliar Nitrogen Concentration

Application of nitrogen in 1963 had no significant effect on foliar N concentration in any year. Even in the untreated trees, however, foliar N concentration was relativey high: the lowest values were 1.59 and 1.26 per cent dry matter in Scots pine and lodgepole pine respectively. Applied phosphate consistently increased foliar N concentration in lodgepole pine but not in Scots pine; the effect was significant only in 1965 when values ranged from 1.39 per cent dry matter at the lowest rate to 1.52 per cent dry matter at the highest rate. Applied potash did not affect foliar N concentration in either species.

(c) Foliar Potassium Concentration

Foliar K concentration in either species was not significantly affected by applied potash. Values in Scots pine ranged from 0.54 per cent dry matter in 1973 to 0.66 per cent dry matter in 1965. In lodgepole pine the corresponding values were lower at 0.4 and 0.46 per cent dry matter respectively.

Rate of applied phosphate did not affect oliar K concentration in Scots pine although values were higher in the phosphate treated plots than in the untreated 'control' plots, but in lodgepole pine foliar K concentration increased with increase in rate of applied phosphate although the differences were significant only in 1969 when concentrations ranged from 0.39 to 0.44 per cent dry matter in the P_1 and P_3 treatments respectively.

4.2 Effects of Minor Elements on Growth and Foliar Nutrient Concentrations

(a) Height growth

The effect of minor element treatment on height increment 1962–1973 is shown in Table 9.

TABLE 9

Effects of minor elements applied in 1963 height increment 1962–1973 (m) of Scots and Lodgepole pines

	Trace element treatment							
Species	Nil	Mo	Co	Zn	B	Mg	Cu	S.E.m. ±
S.P.	2.72	3.06	2.97	2.92	3.03	3.33	2.61	0.32 n.s.
L.P.	3.01	3.42	3.33	2.72	3.32	3.40	3.31	0.26 n.s.

None of the minor elements applied significantly affected height increment over the period of the experiment in either species. Nor was leader growth in either species for the years 1965, 1967, 1969 or 1973 significantly affected by treatment.

(b) Foliar Nutrient concentrations

The foliage of each species was analysed chemically at the end of the 1973 growing season but as with growth there was no statistically significant effects of treatment. The mean values of foliar nutrient concentration for all treatments are shown in Table 10.

TABLE 10
Mean Foliar nutrient concentration of Scots and Lodgepole pines at end of eleventh growing season

	Foliar Nutrient Concentration					
Species	N	P	K	Mg	Zn	Cu
		per cent matter			p.p.m. dry matter	
S.P.	1.68	.10	.58	.10	47	6.2
L.P.	1.42	.09	.47	.08	48	8.1

The concentration of the major nutrients, N, P and K, are similar to those in the previously described experiment with levels being higher in Scots pine than in lodgepole pine, concentrations of N and K appear adequate but foliar P concentration is in the deficiency range eleven years after the application of 40 kg P per ha.

5. Discussion

The results of the experiment clearly demonstrate that P deficiency is the major nutritional factor limiting the growth of Scots and lodgepole pines on the site described and that this limitation can be overcome by phosphate application. However, there are distinct differences in response between the species. The most obvious visual difference was in the habit of the untreated trees and their development following fertilizing. There was a marked lack of apical dominance in Scots pine which did not occur in lodgepole pine although there was little difference between the two in colour and general vigour. Following treatment single straight stems developed on all Scots pine and by the end of the experiment there was no difference in form between the two species.

Other differences between the species were that the growth of Scots pine continued to increase longer than in lodgepole pine and it also increased progressively with increase in rate of phosphate applied whereas in lodgepole pine there was no difference in growth between the two higher rates.

Although foliar P concentrations tend to be higher in Scots pine, especially in the earlier years of the experiment, this cannot account for the difference in length of time over which the two species respond. In the P_2 treatment for instance foliar P concentrations were the same in 1969 (at 0.14% D.M.) and in 1973 (at 0.13% D.M.) but growth pattern over this period was quite different in that annual height growth in Scots pine was increasing while in lodgepole pine it was decreasing. This suggests that the P deficiency level is lower in Scots pine than in lodgepole pine.

Lodgepole pine responded more quickly to fertiliser treatment than did Scots pine, probably because it responded to nitrogen as well as phosphate application. Although the response to nitrogen was statistically significant only for height increment between 1967 and 1969 (inclusive) growth in lodgepole pine was consistently better in the presence of applied nitrogen throughout the experiment. The length of response period suggests that some recycling of applied nitrogen had occurred. Applied nitrogen had no effect on the growth of Scots pine at any stage but the levels of foliar N concentration were considerably above those in lodgepole pine. The fact that foliar N concentration did not fall below 1.59 per cent dry matter even in the untreated plot suggests that Scots pine obtained adequate N from the soil.

Although applied potash did not affect the growth of Scots pine it consistently decreased height growth in lodgepole pine. In spite of this height and presumably dry matter reduction foliar K concentration was not significantly higher in the potash treated plots. Since potash application did not affect N or P uptake it is difficult to account for its effect in decreasing growth.

Although there are many reports of minor element deficiency restricting tree growth (see e.g. Stone 1968, Baule and Fricker,)1970) neither species responded to any of the lements applied. This and the fact that the foliar concentrations of the elements determined (i.e. Mg, Zn and Cu) lie within the intermediate ranges quoted by Leaf (1968) and Stone (1968) suggests that growth in this site is not being limited by minor element deficiency.

The fact that phosphate increased growth for up to ten years after application indicates that neither fication within the soil nor loss by leaching were serious. This is supported by the fact that there was no downslope movement of P. Although the slope was steep (38%) and the P applied in water soluble forms the boundaries between the treated plots and the untreated surrounds remained distinct for eleven years.

6. Conclusions

Phosphorus was applied in two forms, superphosphate and triple-superphosphate. With Scots pine both forms were apparently equally effective, there being positive linear response to increase in rate of elemental P applied. Growth response in lodgepole pine, however, was quadratic with no extra increase at the highest rate of applied P, this being in the form of triple-superphosphate. This could mean that triple-superphosphate is an ineffective source of P for lodgepole pine but this is unlikely and it is more probable that the highest rate (67.5 kg P/ha) exceeds the P requirement of lodgepole pine on this site. It must, however, be remembered that the lodgepole pine in this experiment is an inland type and the P requirement of a more vigorous provenance may be higher.

Although both forms of P applied appear suitable both are more expensive per unit of P than the rock phosphate more commonly used in forestry.

The pH of the soil is within the range found for oligotrophic peat where rock phosphate has been found to be effective (Dickson, 1971) and unless the high P concentration of triple-superphosphate is found to outweigh its extra price rock phosphate would be a more suitable fertiliser. Rates of application should be at least 480 kg per hectare rock phosphate (14% P) for Scots pine and about 330 kg per hectare for an inland provenance of lodgepole pine.

On present evidence application of nitrogen or potash is not justified.

The economics of treating the crop described are complicated by the very long period (25 years) between planting and time of treatment. Effectively, however, application of phosphate to a crop moribund in 1963 has produced a viable, closed canopy plantation by 1973. Without treatment many of the Scots pine were by then dead and the lodgepole pine were in very poor condition. Even if, as seems possible, further phosphate input is necessary before crop maturity this can be done relatively easily by helicopter and the longevity of growth response to a single phosphate application suggests that total fertilising costs for the treatment recommended will not be excessive.

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Silviculture and Management in Relation to Risk of Windthrow in Northern Ireland

R. F. MacKenzie[1]

Assessment of windthrow risk

1. Introduction

In producing a windthrow risk assessment chart (Table 1) the object has been to provide a rational means of deciding what management principles are best suited to any particular site. The degree of risk predicted refers to damage of the kind that can occur under ordinary circumstances.

There are many factors involved in the assessment of wind risk, only some of which are included, and changes in the value of one may alter its relative status with regard to others. Those used are broadly assessed and capable of substantial refinement. For example the gley soil group includes humic gley which is more windthrow prone than gley with a well developed eluviated horizon. Some of the effects are indirect, for example 'geology' combines the effect of land form and exposure, and is also related, by chance, to changing wind speeds over the country. Of the wind itself, its speed, gustiness and turbulence, very little is known, although there are indications that storms may follow a cyclical pattern with 4 or 5 years of high winds being followed by 6 or 7 quieter years, within an 11-year cycle.

The guide must be used with this background in mind and results interpreted and applied in the light of local knowledge and experience.

2. Classification of windthrow risk

Windthrow risk can be assessed for forests in the establishment phase by considering the influence of six site factors. These are: soil type, angle of slope, aspect, altitude, exposure (as measured by the Topex system) and geology. By allocating a degree of risk to each, an overall site assessment can be made as shown in Table 1. It is convenient to recognise four classes of risk:

Very high risk—for sites with a total score of 20 or more points.
High risk—with a score of 16 to 19 points.
Moderate risk—a score of 11 to 15 points.

1. Forestry Division, Department of Agriculture, Belfast.

TABLE 1
Windthrow Risk Assessment Chart

Score / Factor	0	1	2	3	4	5
Soil	Brown Earth	Ironpan	Valley Peat, Podzol	Climatic Peat	Peaty Gley	Gley
Slope	24°+	15–24°	0–4°	10–14°	5–9°	
Aspect		Flat E	S SW W	NE NW	N SE	
Altitude		0–150′ 1,250′+	150′–450′	900′–1,250′	450′–900′	
Topex	100+	31–100	11–30	0–10		
Geology	Old Red Sandstone	Granite	Schist, Silurian	Carbon-iferous	Basalt	Triassic Cretaceous

Score: 20 and over—very high risk
16 to 19—high risk
11 to 15—moderate risk
10 and below—low risk.

Low risk—for those sites scoring 10 points or less.
The application of this method to forest inventory plots indicated that about 14% were classified as of very high risk, 54% fell into the high risk class, 27% were in zones of moderate risk and low risk sites accounted for a remaining 5%.

3. Method of risk assessment

Where forests are extensively managed the areas to be assessed for wind risk can be large, either the whole forest or a readily identifiable part such as a catchment area or a system of hills. In intensively managed forests the area assessed may be much smaller—a few compartments or an outlying block. The smallest unit which can be considered is one bounded on all sites by permanent margins or an area having marked changes in site factors influencing stability.

In an area selected for assessment a reasonably dispersed coverage of not less than 20 randomly located sample plots is needed. Soil and exposure maps are available for nearly all state forests, and these, in conjunction with the Ordnance Survey Map, provide nearly all the information needed to make an assessment of risk. If two-thirds of the plots have a score falling into one risk class then it will usually be acceptable to allocate the whole area to that class. However, in some circumstances it may be appropriate to divide the forest into risk classes, and further sampling may be needed. The variability of the samples will be a guide as to whether this is required.

4. Management options

4.1 Stand Structure

Three silvicultural regimes are open to management: high forest, coppice and coppice with standards. Within the high forest two forms of stand structure are distinguished; selection high forest, which is uneven aged; and regular high forest, which is even aged. Further sub-divisions are possible. The selection forest may be either single stem selection or group selection, and the regular high forest may be clear felled or worked on one of the many forms of shelter wood systems. In Northern Ireland the choice lies between group selection or regular high forest with clear felling. In both cases regeneration is normally artificial.

Windthrow is related to the degree and extent of interruptions to the forest canopy. Because of this group selection high forest is suitable only in low risk areas. The practice of regenerating small areas, from which windthrow timber has been cleared, tends to result in a structure approaching that of the group selection high forest, thus increasing windthrow risk. There are only a few locations where the silvicultural system selected can be other than regular high forest with clear felling, with coupes usually at least of compartment size.

4.2 Production Regime

On high and very high risk sites interruptions to the canopy following racking and thinning, and the damage to root systems by extraction operations, can induce an unacceptable risk of wind damage. On these areas all production should, as far as possible, come from clear felling.

On sites having a moderate risk thinning is optional. The decision as to whether to thin or not may depend on factors other than the degree of risk. Most conifers, and all hardwoods, benefit by regular thinning. It may be possible however with some species, to cease thinning at a fairly early age.

All stands on low risk sites may be thinned. The extra production and improved timber quality off-set the slightly increased possibility of windthrow.

4.3 Rotation Lengths

Rotation lengths are usually those which will give the maximum mean annual increment. Attempts to achieve this on sites with high or very high wind risk may result in forest conditions deteriorating as maturity approaches. Mature stands on these sites have usually experienced a good deal of windthrow, resulting in big areas of unstocked ground, increased risk of disease, dangerous working conditions, high production costs and appreciable timber de-grade with fungal infection. For these reasons shorter rotations, may be recommended as.in Table 2, based on achieving 95 % of the maximum mean annual increment.

TABLE 2
Recommended short rotation minimum ages for uniform conifer forest with no thinning, clear felling and artificial regeneration on high and very high wind risk sites

	Local Yield Class									
Species	24	22	20	18	16	14	12	10	8	6
Sitka spruce	36	38	39	41	43	45	47	49	52	54
Norway spruce		47	47	49	51	54	56	60	64	72
Japanese larch						29	30	32	34	36
European larch							35	37	40	44

On sites classified as having a moderate risk there may be a choice as to whether to attempt to achieve the maximum mean annual increment of rotation or not. This decision depends on the state of the stand as it approaches maturity. If there are signs of instability—bent tip in Sitka stands, scattered windthrow, evidence of 'pumping', etc.—then early felling is indicated.

For low risk sites no top height limits need be applied. Rotations will be those of the maximum mean annual increment.

5. Establishment operations

5.1 Layout of Plantations

Turbulence from edge effect is a major cause of damage to plantations, but the risk can be reduced by careful planning.

On very high risk sites roads and rides should be kept to a minimum and, where possible, should be orientated in the direction of the prevailing wind. Roads or rides should not be laid out along contours about one-third down lee slopes. Very high risk sites will not be thinned and racks should not be incorporated in the layout unless associated with main drainage. The same principles should be applied to roads and rides on high risk sites but other racks can be included if required for inspection purposes. They must, however, be no more than 5 m wide so that canopy can close by the time the top height of the stand reaches about 10 m. The chance of damage on high or very high risk sites can also be reduced by establishing the greatest possible area of plantation in the shortest time and by avoiding big differences in age between adjoining stands. Where this cannot be done then establishment should proceed into the prevailing wind so that the youngest stands are on the windward side of the forest.

On sites of low or moderate risk no modifications are required.

5.2 Ploughing and Planting

Root plant development may be restricted on ploughed ground. This can be an important factor in increasing wind damage.

On very high risk sites ploughing should be restricted to the minimum absolutely necessary to provide a planting medium and remove surface water. Double mould board ploughing is desirable. Plough furrows should be shallow to encounter cross-rooting and, where possible, be parallel to the prevailing wind. Cut and spread turves can be used for planting. The plough ribbon should be as far from the plough furrow as possible. Maximum permissible planting spacings should be used. Wheeled vehicles can destroy top soil structure reducing natural drainage and causing ponding. This effect may persist for very long periods. Tracked machines should be used whenever available.

Modifications are also required when ploughing high risk sites. Turf planting is desirable, but, if not practicable, then the site should be double mould board ploughed, preferably into the prevailing wind, and with the ribbons placed as far from the furrow as possible. Deeper furrows are practicable on some site types if these have improved profile drainage. The use of low ground pressure machines is advisable. Plants are to be widely spaced.

Where the risk of wind damage is classed as low or moderate no particular precautions are required.

5.3 New Main Drainage

Drainage operations can be associated with damage to soil structure and tracked machines should be used for all drainage works except where the impedence results from hard pans.

Drains are likely to restrict root spread and trees on the edges are at greater risk. As drainage intensity increases more trees may be affected, particularly on those sites where sub-soil drainage is impractical. The degree of risk can be reduced by allowing the maximum possible development of root plates, and on high and very high risk sites no trees should be planted within 3 m of the drain centre on the leeward side and 2 m on the windward side. The effect of increasing drainage intensity on stability is controversial. Current practise is to contour drain wet soils at 50 to 100 m spacing with falls of $\frac{1}{2}$ to $1\frac{1}{2}$°.

5.4 Fertilising

Fertilising does not influence the degree of wind risk very much. As with all other operations involving the use of machinery, ground damage is a danger. On very high risk sites hand or aerial application of fertiliser is recommended. On high or moderate risk sites ground machinery, preferably tracked, can be used. On low risk sites there are no machine constraints.

Canopy irregularities can cause turbulence and may increase instability. Assessment of site fertiliser requirements with a view to obtaining an even canopy is desirable on high and very high risk sites.

5.5 Selection of Species

Selection of species will generally be made on criteria other than stability; but there a differences in rooting and crown characteristics that can have an important effect.

On high and very high risk sites only species having a good tolerance of anaerobic soil conditions, an ability to develop wide, strong root plates, or crown characteristics that reduce wind resistance, are suitable. These are likely to include Sitka spruce, which develops a wide root plate, and Lodgepole pine, which roots deeply in peat and has lower crown wind resistance. Alder can root strongly in clay-rich mineral soils and is leafless in the winter when risk is greatest. Other species will have limited use except for aesthetic purposes. Larches have been widely planted on these sites in the past. Because of their very low tolerance on anaerobic soil conditions and their liability to various root rots they must not be used under any conditions of impeded drainage, and never planted on ploughed ground.

6. Forest improvement

6.1 Roads

Most wind damage associated with roads in established plantations is related to damage to root systems when new roads are made through established crops or to turbulence caused by the edge effect.

On very high risk sites no new road works should be undertaken after canopy has closed. On high risk sites, however, new roads can be made provided the top height of the stand has not passed 7 m and on sites with moderate risk new roads can be made provided a stand top height of 10 m has not been exceeded. When maintaining roads on very high or high risk areas no trees should be removed from road edges nor should new roadsise drains be dug. In areas of moderate risk roads can be widened, new drainage installed, and edge trees removed if necessary.

6.2 Drains

The risk of wind damage can be increased by cutting through established root systems during maintenance operations or by allowing ponding to occur thus raising water tables and killing roots.

On very high and high risk sites drain maintenance should consist of clearing blockages only. No new drainage systems should be made after top heights reach 5 m. The same constraint applies to new drains in plantations on moderate risk sites although existing drains can be widened and deepened provided damage to root systems is kept to a minimum.

6.3 Fertilising

When fertilising established plantations the constraints are similar to those given above for young plantations (Section 5.4).

6.4 Respacing

Windthrow tends to be more severe in closely spaced crops once the canopy has been broken. Respacing at an early age may help to reduce the extent of the damage.

In young stands in areas of high or very high risk, where the GYC is assessed at 16 or more, and there are at least 3,500 stems per hectare respacing may be considered.

7. Harvesting

Harvesting operations involve creating breaks in the forest canopy making stands liable to edge and turbulence effects. Extraction can cause damage to roots and soil structure.

7.1 Thinning

Stands on high or very high risk sites will not normally be thinned but there will be situations, as in the case on larch, hardwood and some pine plantations, when the silvicultural need to thin may be more important than the increased chance of windthrow that follows. In these circumstances racks, if essential, should if possible be orientated towards the prevailing wind. Line thinning increases wind risk and is not recommended. Stands do not stabilise until about 4 years after thinning. Cycles should not, therefore, be less than this and wherever possible, 5 or 6-year cycles should be adopted.

SUMMARY OF SILVICULTURE AND MANAGEMENT

			Risk of
	Operation	Low	Moderate
MANAGEMENT	Stand Structure	Regular high forest or group selection.	Regular high forest preferably.
	Production Regime	Thin	Optional depends on stand structure and species.
	Rotation	Max MAI or long	Choice depends on the state of the stand when approaching maturity.
ESTABLISHMENT	Layout of Plantations	No Constraints	No Constraints
	Ploughing	No Constraints	No Constraints
	New Main Drains	Unlikely to be required	Wheeled machines are undesirable.
	Fertilising	No Constraints	
	Selection of Species	No Constraints	There may be some constraints depending on site conditions
IMPROVEMENT	Roads	No Constraints	No roads after stand height 10 m. Widening undesirable.
	Drains	No Constraints	No new drains after 5 m. Do not deepen if cross rooted.
	Fertilising	No Constraints	Wheeled machines undesriable.
HARVESTING	Thinning	No Constraints	Thin before 11 m height. Care with rack directions. Long cycles heavy thinning 4 years minimum for spruces. Avoid line thinning.
	Felling	No Constraints	Fell into wind. Group felling not recommended.
	Windthrow timber	Remove and utilize	Remove and utilize.
	Extraction	No Constraints	No wheeled machines if wet.

IN RELATION TO WINDTHROW RISK

wind Damage

High	Very High
Regular high forest only.	Regular high forest only.
No-thinning	No-thinning
Short	Short
Racks undesirable, if essential then narrow widely spaced. Roads and rides parallel with wind.	Minimum number of racks. Road and rides parallel with wind.
Regenerate large areas over short periods.	
DMB, furrow depth depends on site, ribbon back from score, parallel with wind. Tracked machines best. Wide spacing.	DMB plough, shallow furrow, ribbon back from score, parallel with wind. Consider turfing. Tracked machines. Wide spacing.
Tracked machines. No plants within 2 m windward 3 m leewards.	
Hand or aerial application preferable tracked machines only. Careful application to produce even growth.	
Most spruces, PC. No larches.	SS or Alder only.
No roads after stand height 7 m. No felling edge trees.	No new roads. No felling edge trees.
No new drains after 5 m.	No new drains.
Do not widen or deepen drains—clear blockages only.	
Hand or aerial applications preferable tracked machines only. Desirable to try to bring areas out of check.	
No thinning. Respacing of vigorous stands GYC 16, and over with more than 3,500 stems/ha.	No thinning.
Clear fell or fell into wind.	Clear fell to established margins.
Removal depends on extent of damage.	Do not touch or consider clear felling
Horse, cable or low ground pressure machines only.	Horse or cable only.

On moderate risk sites forests are more likely to be managed within thinning working circles. Rack layout is less important in these circumstances but wide racks should be avoided and line thinning is undesirable. Again cycles should not be less than 4 years.

7.2 Felling

Stands on very high risk sites shoule be felled out to stable margins. On high risk sites similar treatment is desirable, but if whole blocks cannot be completely felled to stable margins, then fellings should be planned to proceed towards the prevailing wind. Advantage should be taken of any zones of stability in locating felling coupes.

On sites of moderate risk felling towards the wind is desirable if the period is likely to extend for more than a few years. In any event felling plans should be prepared for clearing to established edges within a period not exceeding about 10 years. Group fellings are not recommended.

7.3 Dealing with Windthrown Timber

When wind damage has occurred in regular high forest it may be necessary, for economic or biological reasons, to remove the trees involved. On low and moderate risk sites quick utilisation of windthrown timber is likely to be possible under most circumstances. On very high risk sites removal is not recommended. In the case of high risk sites the action will depend upon the extent of the damage; with low levels of damage timber should not be extracted, but where damage has been extensive clear felling should be considered. In intermediate cases felling should proceed either to where changing site conditions improve stability or to the outer edge of the marginal zone of leaning trees on the lee side of the windthrown area, the leaning trees themselves must not be removed.

7.4 Extraction Operations

To avoid damage to soil structure on very high risk sites cable extraction should be used wherever possible. The use of this method is desirable on high risk sites, but low ground pressure machines are acceptable if free operation over the whole area is possible and work is testricted to the drier periods of the year. On both these site types it may be worth considering the use of horses.

There are no constraints on extraction operations in low risk areas, but in moderate risk areas wheeled vehicles should not be used when conditions are wet and rutting is likely to occur.

The Influence of Tracheid Length and Density in Sitka Spruce[1]

DECLAN WARD[2] AND J. J. GARDINER[3]

Introduction

THE influence of tracheid length upon wood properties has been demonstrated by several research workers. Watson *et al.* (1952), quoted by Elliott (1960), have shown a definite correlation between the tensile strength of paper and tracheid length. Strongly associated properties are bursting strength and folding endurance. Dadswell (1957), quoted by Elliott (1960), considers that the average tracheid length is one of the most important structural features related to wood quality and one of the easiest to measure.

Wood density is the simplest and most useful index of the suitability of wood for many important uses and is very easily and quickly measured. There is a high degree of correlation between density and the mechanical strength of all woods (Mitchell, 1960). Density is therefore a primary factor in the segregation of structural grade timbers that command premium prices, and also in the selection of material for transmission poles and other uses where strength is of major importance.

The northwest American tree species Sitka spruce *(Picea sitchensis* (Bong.) Carr). is the most important exotic conifer in Irish forestry. In 1972/73 it comprised 65.7% of the various species established in State plantations (Report of the Minister for Lands, 1973). Sitka spruce is generally planted pure, in upland regions where it's main requirement, for adequate moisture, can be most easily met. In general, the timber is of uniform light colour without a distinct heartwood. It normally has an average nominal specific gravity of approximately 0.33 and a growth rate of about 3 to 8 annual growth rings per inch (Wood & Bryan, 1960).

A considerable amount is known about the general behaviour of Sitka spruce as a plantation species but, until now, most research has been concerned with improving growth rate with consequent

1. Based on a dissertation submitted for the M. Agr. Sc. degree, University College, Dublin 1975.
2. Present address: Research Branch, Forest and Wildlife Service, Bray, Co. Wicklow.
3. Forestry Department, University College, Dublin.

increases in yield through such practices as fertilisation. Little is known of the variation patterns within the tree and of it's response to various silvicultural treatmenıs at a basic wood structure level.

It seems therefore desirable to assess the effects, if any, of silvicultural treatment on two wood properties namely: tracheid length and density.

Factors contributing to Variation in Wood

Wood cells originate as a result of divisions of the cambium cells. However, variation in cambial activity commonly occurs, not only between trees, but also during the lifetime of an individual tree.

The result of varying cambial activity is that the average length of a population of cambial initials does not remain constant. As the cambial zone moves outwards with increasing diameter of the stem, the average length of cambial initials usually increases over the first few centimetres and then becomes less predictable. This variation in the length of cambial initials is the primary cause of variations in wood quality.

The wood formed within and immediately below the active crown is known as juvenile wood. It is characterised anatomically by a progressive increase in the dimensions of the component cells and it also exhibits corresponding changes in form, structure and disposition of the cells of successive growth rings (Rendle, 1960). Research has shown that for most temperate conifers the wood in the first ten to fifteen rings from the pith is characterised by:

(1) Rapidly increasing tracheid length of the order of 300% (Dinwoodie, 1963).
(2) Whole-ring density values which fall from a maximum value and thereafter rise slowly (Brazier, 1967).
(3) Cell wall thickness which decreases in the earlywood and increases in the latewood of the annual ring (Brazier, 1967).

The major changes in wood formation and quality are therefore in the lower stem region beneath the living crown.

Wood formation is affected by a variety of environmental conditions. Variable weather conditions produce variation in wood quality because of fluctuations in the growing conditions. Liese & Dadswell (1959), quoted by Bannan & Bindra (1970), after examination of many trees in both northern and southern hemispheres, reported that rings were widest and the longitudinally orientated cells shortest on the sunny side of the stem. It was concluded that warmth stimulated cell division and favoured reduced cell length. Furthermore, Derby & Gates (1966) have shown that cambial temperatures were highest on the south and east sides of aspens in Colorado, U.S.A. It is to be expected therefore, that a mosaic pattern of cambial heating would prevail in the tree, with changes from hour to hour depending on the angle of insolation and branch arrangement.

Bannan & Bindra (1970) noted inequalities in the amount of radial growth around the stem. Working with three species; White spruce (*Picea glauca* (Moench Voss), Lodgepole pine (*Pinus contorta* var. *latifolia Engelm.*), and Eastern white pine (*Pinus strobus* L.) they showed that growth rings tended to be wider on the east than on the west side of the stem. Because this pattern of unequal growth is of common occurance in trees of the northern hemisphere, where the prevailing wind is from the west, it was concluded that the two phenomena were related.

Within the forest, control of the finished product can be exercised by manipulation of an array of silvicultural tools, including genetics, fertilisation and spacing. This study is concerned with the last of these three.

Systematic Variation of Wood Properties within the Stem

1. Tracheid Length

The foundation of the study of tracheid length variation was laid down by Sanio in 1872. He presented the results of his studies on Scots pine (*Pinus sylvestris. L.*) in a set of five conclusions, which are now generally referred to as 'Sanio's Laws' (Baily & Shepard, 1915). Briefly they are:

(i) In a radial direction from the pith, tracheid length increases until a maximum is reached. From this point outwards the length remains constant.

(ii) Longitudinally from the stump upwards tracheid length increases to a maximum, thereafter decreasing with further height increase.

The constant tracheid length reported by Sanio has not been entirely corroborated. Bailey & Shepard (1915), working on basal sections of four conifers, found that the initial increase was followed by wide fluctuations. Furthermore, Gerry (1916), reported that in Douglas fir (*Pseudotsuga menziesii* (Mirab. Franc.)) the increase in length up to 20 years was marked, but thereafter became erratic.

(a) Variation within the Annual Ring

There is general agreement in the literature that in all species having distinct growth rings, there is radial variation in the length of tracheids within any given annual ring.

Dinwoodie (1961), has shown that in Sitka spruce the last formed tracheids in the ring are 5 % to 10 % longer than those at the beginning of the ring, and 17 % to 30 % longer than those of minimum length in the centre of the ring. This does not apply to the three rings nearest the pith.

(b) Variation in Tracheid Length outwards from the Pith at any one level

All investigations into this aspect of tracheid length have recorded the same general trend. Cell length in the ring nearest the pith is very short (0.5 to 1.5 millimetres on average in conifers), but increases rapidly outwards in the first few rings. After this, the rate of increase declines until a maximum tracheid length is reached. Maximum tracheid length is generally 3 to 5 times greater than the initial length (Dinwoodie, 1961).

Considerable disparity appears, firstly as to whether this length increase outwards is associated with increasing ring number or with linear distance from the pith as outlined by Anderson (1951). Secondly, the controversy arises as to whether tracheid length, after increasing initially, remains constant or fluctuates.

(c) Variation in Tracheid Length with increasing Height in the Tree

This relationship may be studied from two different aspects. Either a single ring may be followed upwards in the growth sheath or, a growth ring at a constant number of rings from the pith may be traced upwards.

It is generally accepted that within the growth ring, tracheid length increases upwards for a certain distance before decreasing progressively to the top of the tree. The average length of the tracheids at the top of each ring is generally less than that of the tracheids at ground level (Dinwoodie, 1961). The position of maximum tracheid length in each growth ring, therefore, will be located at progressively higher levels as successive growth rings are formed.

There is a sparsity of data regarding the variation in tracheid length upwards in growth rings at a fixed number of growth rings from the pith. With the exception of the first formed ring, tracheid length has been found to increase with increasing height up to some point in the stem, after which, length remained constant or declined (Chalk, 1930; Elliott, 1960; Dinwoodie, 1961). In the first formed growth ring tracheid length remained constant or varied extremely little up the stem (Bisset & Dadswell, 1949).

(d) The Effect of Growth Rate on Tracheid Length

Attempts to correlate the increase in tracheid length with the age of the tree, width of growth ring and linear distance from the pith have been made by several researchers. Trendelenburg (1939) is quoted by Ahmed (1970) as having established that in spruce, wood with broad annual rings has shorter tracheids than wood with narrow annual rings. These findings were confirmed by Bisset *et al.* (1951). Early work (Chalk, 1930) indicated that there was an inverse relationship between tracheid length and ring width, recording a correlation coefficient of 0.742 ± 0.005 for Sitka spruce. Elliott (1960) investigating a 41 year old Sitka spruce stem concluded that age has a significent correlation with tracheid length, while ring width showed a negative correlation with tracheid length.

2. Density

Density is not a simple characteristic of wood, it is complex of the effect of several growth and physiological variables compounded into one fairly easily measured wood characteristic. In the anatomical sense, density is a function of the ratio of cell wall volume to cell void volume and is consequently affected by cell wall structure, average cell dimensions, lumen dimensions, amount of resin and extractives and a volume of non-fibrous elements such as rays (Elliott, 1970).

(a) Variation in Density with increasing Height in the Tree

It is long known that, for many conifers, density decreases with increasing height in the stem. In certain conifers, notable the spruces, density does not markedly decrease with height, but rather does not vary significantly or may even increase with increasing height (Farr 1973).

(b) Variation in Density outward from the Pith at any one Level.

Density also varies with the distance outward from the pith at any one height level. For young and semi-mature trees density is almost always found to increase from the pith outwards.

Although the general pattern of density variation has been established, it is impossible to say whether the trend is related to position in the tree or to age. The two factors appear to be completely confounded (Spurr & Hsuing, 1954).

(c) Earlywood, Latewood and Wood Density

Earlywood and latewood density values are not constant within a species or even within a single tree. They vary from juvenile to adult wood and also with conditions of growth. The nature of the transition from earlywood to latewood in each year's growth can also have a marked effect on average wood density (Harris, 1967).

In many conifers, the basic density of the latewood zone is more than twice that of earlywood (Paul, 1939; Fry & Chalk, 1957), thus any increase in the proportion of latewood inevitably leads to an increase in whole-ring basic density.

(d) Silvicultural Considerations in relation to Wood Density.

Paul (1946), has emphasised that wood density values can be raised if the proportion of latewood laid down is increased. Thinning, pruning and spacing control might be used to achieve this end. Thinning may have various effects. In Loblolly pine (*Pinus taeda*), release has, under various conditions, been shown to increase and sometimes decrease average density, or to have no discernable effects (Spurr & Hsuing, 1954). In addition spacings of 4×4 feet, 6×6 feet and 8×8 feet had only minor effects on average wood density (Jayne, 1958). Up to the stage of canopy closure the effect of initial spacing on basic density is not very clear. Evidence supporting an increase in value with close initial spacing is offset by evidence indicating that, within the limits of normal silvicultural practice, initial spacing has little significant effect on basic density values (Elliott, 1970).

MATERIALS AND METHODS

Materials

1. The wood used

Wood samples for all of the preliminary experiments were obtained from a 37 years old stand of Sitka spruce in Knockrath Woodlands, Laragh, Co. Wicklow.

The wood samples examined in the major experiments were taken from Sitka spruce stands at Drumhierney Plantations, Leitrim, Co. Leitrim. The stands from which samples were taken were established in 1954 at spacings of 2.4×2.4 metres (8×8 feet), 3.6×3.6 metres (12×12 feet), and 4.57×4.57 metres (15×15 feet), and have not been thinned since establishment (Dillon, 1970).

Sampling in most cases was by means of a 5 millimetres diameter increment borer. However, at Knockrath Woodlands a single stem was felled and discs approximately 2 centimetres in width were cut.

2 Laboratory Materials

The digestion solution used consisted of a 50:50 mixture of glacial acetic acid (CH_3COOH) and '100 volumes' hydrogen peroxide (H_2O_2).

The agar used was 'Oxide' Ionagar.

Methods

1. Field Operations

Non-destructive sampling was used, with one exception, throughout the investigation. It was therefore necessary to take most samples by means of an increment borer. Due to the general unavailability of large diameter (10 to 12 millimetres diameter) borers it was decided to investigate the possibility of using the method of sampling developed by Polge (1967). In this a Pressler 'Swedish-type' 5 millimetres diameter increment borer is driven into the tree at an angle of 30° to the stem.

2. Laboratory Operations

In the case of disc samples, single whole growth rings selected for maceration or for density determination, were extracted from the disc by means of a chisel. A scapel was used in the case of cores. In both cases rings were rendered more distinguishable with an aqueous solution of safranin (Kase, 1935; Hornibrook, 1936).

In the sampling of tracheids for transferance onto microscope slides a standard procedure, involving successive dilutions was established to ensure as far as possible that random sampling was being employed.

At first a sample size of 45 tracheids was adopted for assessing mean tracheid length. This was later increased to 50, with reference to Harris (1966) and Burley (1969).

Each slide in preparation for the application of the tracheid smear, was first covered with 1 or 2 millilitres of 2% Ionagar which was then allowed to dry out leaving a thin film on the slide. The tracheids were found to be secured to the slide on drying.

Tracheid length was measured by projecting an image of the slide mounted tracheids on a screen by means of a projection microscope. The magnification used was 100X and tracheid lengths on the screen were measured by means of an opisometer. Density was assessed on whole rings in the case of disc samples and on groups of whole rings in the case of core samples. In approaching wood density measurement from an ecological standpoint, density based on green volume and oven dry weight is preferable. It is an easily replicable value and its use avoids the complications arising from wood shrinkage while drying (Spurr & Hsuing, 1954).

Details of the Experiments

1. The Angle of Sampling with the Borer

Polge (1967), has suggested that increment cores taken at an angle of 30 degrees to the tree can be used when taking samples for tracheid length measurements. However, sampling at any angle with a borer must necessarily cut many tracheids. These cut tracheids make it difficult to distinguish and measure uncut tracheids. Hence it was considered desirable to examine this aspect of core sampling before proceeding to use this method routinely.

The Pressler borer is most easily driven at 90 degrees to the tree. It was therefore decided to assess and compare the number of full-length tracheids present at 4 different angles; 90, 45, 40 and 35 degrees using a ratchet handle to drive the borer.

2. A Comparison of Tracheid Length when using Disc and Core Samples

There are numerous suggestions in the literature, notably Hart & Hafley, (1967) that core sampling introduces a bias in favour of shorter tracheids.

The measurement of only the uncut tracheids from macerated cores could result in both the mean and variance of the tracheid length population being underestimated.

It was therefore decided that a disc, of approximately 2 centimetres width, be compared to a Pressler 5 millimetres diameter increment core taken from the centre of the same internode, for assessing mean tracheid length.

At the approximate midpoint of the nearest internode to 10% total tree height an increment core was taken at 35 degrees on the east side. The tree was then felled and at the same point a disc of approximately 2 centimetres width was taken and marked on the east side.

The 5th and 10th rings from the bark were selected in both cases.

3. Distribution of Tracheid Length and Density in a Single Stem of Sitka spruce

A single stem of Sitka spruce was felled in Knockrath Woodlands. Total height was assessed in metres and disc samples of approximately 2 centimetres width were taken at the approximate midpoint of the nearest internode to a series of percentage heights. These were 10, 20, 30, 40, 50, 60, 70 and 80% height. As compression wood was suspected of being present on the north radius of the disc growth rings were selected from the east side. The single selected growth rings were counted from the pith and were intended to represent a class of growth rings with an interval of 5 growth rings. In this way the rings selected were the 3rd growth ring from the pith representing the class 0–5, the 8th representing the class 5–10 and so on, for all heights sampled. The samples were macerated and slide mounted. Mean tracheid length was assessed in millimetres based on a sample size of 45 tracheids.

For the assessment of density whole growth rings were selected from both east and west co-ordinates so that a comparison could be drawn between the different values. The growth rings selected were the 4th, 7th, 12th, 17th, from the pith at the 10% height level. The 7th growth ring from the pith was selected for each discrete percentage height level from 10 to 80% total height. Green volume was assessed in cubic metres and oven dry weight in Kilogrammes. Density was expressed in Kilogrammes/cubic metre.

4. The Influence of Spacing on Tracheid Length and Density.

Information was not available with regard to the mean and standard error of tracheid length in Sitka Spruce in Drumhierney Plantations. Consequently, it was not known how many trees should be sampled. In the absence of a pilot survey it was decided to adopt a sample size of 15 trees, with reference to Henderson & Petty (1972) and Joyce (1975).

To ensure, as far as possible, that random sampling was being employed in the selection of trees for sampling, maps of the area with all trees numbered in the rows were consulted (For. Dept. U.C.D., 1970). 15 random numbers were extracted from a table of random numbers for each spacing and the trees located on the map and subsequently in the field in this manner. It was decided to use 10% height on the east side of all selected trees, as the sampling point.

Total tree height (in metres) was assessed using a blume leiss hypsometer. 10% height was located using a metric measuring tape. A core was then taken at 35 degrees to the tree. A total of 45 cores were taken, over the 3 spacings, in this manner. The average time taken to locate each sample tree and take a core was 15 minutes.

In the laboratory growth rings were counted from the bark in order to be able to compare rings of similar age. In this way the 5th and 10th were selected and macerated and density assessed for the interval of growth rings i.e. the 6th to the 9th inclusive. Mean tracheid length was assessed in millimetres based on a sample size of 50 tracheids.

Results

1. Angle of Sampling

It was found that, in Sitka spruce, it was not possible to take samples at an angle of 30 degrees to the vertical axis of the tree. Unbroken, clean cores could, however be successfully taken at angles of 35, 40, 45 and 90 degrees provided that quarter turns of the borer were used to obtain a clean initial cut particularly at the lower angles.

A core sample which is taken at 90 degrees to the tree has a circular tangential face. The taking of a core at an angle of less than 90 degrees produces an elliptical tangential face. Since the effect of taking a core at an acute angle results in an increase in the long diameter of the ellipse and since tracheids run parallel with this diameter it follows that sampling with a borer at an acute angle produces a considerable increase in the number of uncut tracheids in the core.

The results in Table 1, show that with decreasing angle of boring the number of uncut tracheids increases significantly, such that the number present in the core taken at 35 degrees is about four times greater than that in the core taken at the normal angle of 90 degrees. Furthermore, within each treatment—angle core the number of full length tracheids is consistently higher in the 10th growth ring than in the 5th growth ring from the bark. This might indicate that there is a greater number of shorter uncut tracheids present in the 10th ring position than in the 5th ring position.

TABLE 1

The numbers of Uncut Tracheids at 4 different angles of Boring

Treatment Angle	90°		45°		40°		35°	
Rings from Bark	5	10	5	10	5	10	5	10
Totals	45	74	108	121	167	192	209	227
	119		229		359		436	

2. A Comparison of Core and Disc samples for Tracheid Length assessment.

It was found that in the case of growth rings from the disc sample 3 slides per ring were sufficient to supply the required sample of 45 tracheids. In the case of the core sample 6 slides per ring were required, the reason being the relatively greater amount of cut tracheids present.

Statistical analysis showed that for each growth ring sampled no significant difference in mean tracheid length existed between disc and core samples.

3. Distribution of Tracheid Length in a stem of Sitka spruce

The maximum mean tracheid length occurs in the 20–25 ring class from the pith at the 30% height level. The minimum occurs in the 0–5 ring class from the pith at the 70% and 80% height levels.

Variation is traced as illustrated in Fig. 1.

(a) *Variation in Tracheid Length with Age*

From Fig. 1. Tracheid Length versus % Height for the 6 ring classes from the pith, it is evident that in all 8 discs tracheid length increases with age from the pith.

(b) *Variation in Tracheid Length with Height*

Generally, tracheid length in each ring class increases and reaches a maximum value between 30% and 50% height in the stem. Only in the ring class (0–5) does it present a marked continual decrease.

(c) *The Effect of Rate of Growth on Tracheid Length*

At the 10% height level tracheid length shows a significant negative correlation with ring width. Table 2 shows a marked continual decrease.

simple order correlations are significant.

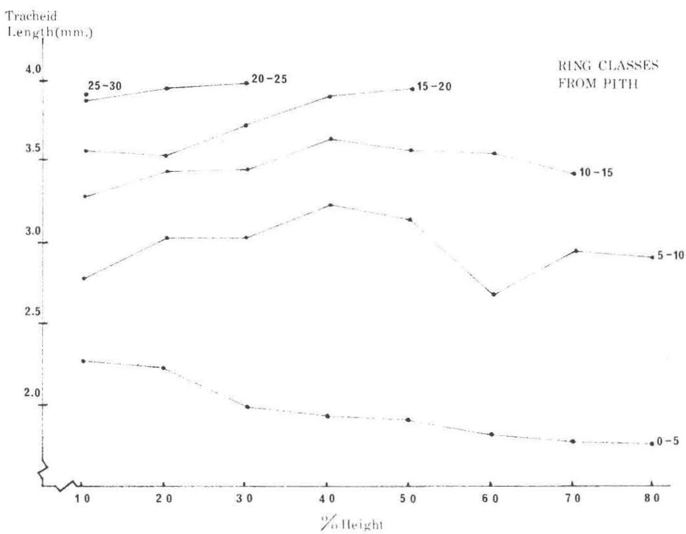

Figure 1: Relationship between tracheid length and per cent height for each ring class for the pith.

TABLE 2

Correlation coefficients between Tracheid Length, Age from the pith and Ring width at the 10% height level in a stem of Sitka spruce

Statistic	Correlation Coefficient	Level of Significance
Tracheid Length/Ring Width	—0.8133	5%
Tracheid Length/Age	+0.9710	1%
Age/Ring Width	—0.8459	5%

4. Distribution of Density in a stem of Sitka spruce

Table 3 presents the results obtained from the east side of the tree in the horizontal and vertical directions. It can be seen that the 10% height level density values (kg/m³) for the selected growth rings, increase generally, from pith to bark. In the vertical direction, in the 7th growth ring from the pith density increases from 281 kg/m³ at the 10% level to 364 kg/m³ at the 40% height level, decreases and rises again to reach it's maximum value of 386 kg/m³ at the 70% height level.

TABLE 3
Distribution of Density (kg/m³) in a stem of Sitka spruce

Rings from the Pith	% Height							
	10	20	30	40	50	60	70	80
4	256							
7	281	349	364	364	306	314	386	343
12	276							
17	325							

5. The Effect of East and West sampling on Density (kg/m³) in a stem of Sitka spruce

Analyses of variance of the effect of east and west sampling on density for both the horizontal and vertical directions, show that there is a statistically significant difference (at the 5% level in the horizontal direction and at the 1% level in the vertical direction) between east and west density values in the tree sampled. These analyses showed also that there were significant differences in density values from pith to bark and also with increasing height in the stem at the 5 and 1% levels of significance respectively. Results and analyses are presented in Tables 4 and 5.

TABLE 4
A comparison of East and West Sampling for Density (kg/m³) with increasing height in the stem

Direction	% Height							
	10	20	30	40	50	60	70	80
East	281	349	363	363	306	314	386	343
West	301	389	408	398	392	385	426	403

Analysis of Variance

Source	df	Mean Square	F
Height	7	23.83	10.605***
East/West	1	98.90	44.004***
Error	7	2.24	

***=Significant at 1% level.

TABLE 5
A comparison of East and West sampling for density (kg/m³) with increasing ring number from the Pith

Direction	Ring Number from Pith			
	4	7	12	17
East	256	281	276	325
West	275	301	321	385

Analysis of Variance

Source	df	Mean Square	F
Rings	3	89.90	41.85**
Direction	1	25.45	11.85**
Error	3	2.14	

**=Significant at 5% level.

6. The Influence of Tree Spacing on Tracheid Length in Sitka spruce

In the design of this experiment it was considered unlikely that there would be any difference in wood properties due to spacing until the closest spacing, 2.4×2.4 metres (8×8 feet) had closed canopy. This was thought to be at approximately 7 years after planting. Hence, the corresponding growth rings near the pith were ignored. It was, furthermore, thought that differences in wood properties between the various spacings would be most likely to occur as the plantations closed canopy. Hence, in the examination of tracheid length only 2 annual growth rings, i.e. the 5th and 10th rings from the bark were examined. Any variation in tracheid length due to spacing should, theoretically, be found in those rings.

The experimental design was a 3×2 factorial. Factor S was spacing at three levels, one for each spacing. Factor R was growth rings from the bark at two levels, one for each growth ring sampled. Fifteen trees were sampled per spacing.

Despite the non-significant results obtained on comparing disc and core samples for mean tracheid length it was decided to utilise a bias correction factor proposed by Hart & Hafley (1967) to achieve a relatively unbiased estimate of the tracheid length population mean. This factor used the variance of each calculated mean tracheid length.

$$U = L + B.$$

where, $$B = \frac{S^2}{C-L} \frac{(k^2+1)}{(k^2-1)}$$

when, $$k = \frac{C-L}{S}$$

where, U = Unbiased estimate of the mean of the tracheid length population.
L = Sample mean tracheid length.
B = Bias estimate in sample mean.
S^2 = Sample variance.
S = Sample standard deviation.
C = Average chord length of the radially trimmed core (Found to be 7 m.m. in material used).

Mean tracheid length (m.m.) was based on a sample of 50 randomly selected tracheid lengths. The calculated B value varied from 0.01 to 0.05 m.m. For example, a sample with a mean of 2.43 m.m. and a standard deviation of 0.90 acquires a B value of 0.02 and becomes 2.45 m.m.

Results are presented in Table 6. The value in each cell is the mean

TABLE 6

The Influence of Tree Spacing on Tracheid Length in Sitka spruce

Rings from Bark	Spacing (m)		
	2.4 × 2.4	3.6 × 3.6	4.57 × 4.57
5th	2.95	2.94	3.08
10th	2.62	2.52	2.57

Each figure is the mean of 15 trees per spacing.

Analysis of Variance

Source	df	Mean Square	F. Value
Spacing (S)	2	0.074	1.61 n.s.
Rings (R)	1	4.003	87.02***
S/R Interaction	2	0.059	1.28 n.s.
Error	84	0.046	

n.s.: not significant
***: significant at 1% level.

of the fifteen corrected mean tracheid length values per ring per spacing. Statistical analysis showed that varying initial spacing in this plantation had no effect on mean tracheid length.

Between 1ings, mean tracheid length differences were found to be significant at the 1% level while there was no significant interaction between factors.

7. The Influence of Tree Spacing on Density (kg/m³) in Sitka spruce

In the same cores from which the 5th and 10th growth rings from the bark were selected for tracheid length assessment, the interval of growth rings i.e. the 6th to the 9th was, in one piece, assessed for density. The experiment had a completely randomised design. However, 4 cores were found unsuitable due to being twisted or broken.

Consequently, the data were analysed using Harvey's Least Squares Analysis of Data with Unequal Sub-Class Numbers (Kelleher, 1975). The results, presented in Table 7, show that spacing had a statistically significant effect (at the 1% level) on wood density.

TABLE 7

The Influence of Tree Spacing on Density (kg/m^3) in Sitka spruce

Spacing (m)	2.4×2.4	3.6×3.6	4.57×4.57
Density (kg/m^3)	389	310	281

Aanlysis of Variance

Source	df	Mean Square	F. Value
Spacing	2	284.05	15.26***
Error	38	25.16	

*** = significant at 1% level.

Discussion

While considerable details are available concerning tracheid length and density in wood, there is little information as regards the influence of silvicultural practices, such as tree spacing, on these wood properties. The experiment reported in this paper on the influence of spacing on tracheid length in Sitka spruce detected no statistically significant effect on tracheid length. It is possible ,however, that sampling for tracheid length within the growth ring was of insufficient intensity to estimate the mean with sufficient precision to detect small differences. At the 3.6×3.6 m. spacing approximately 60% of the total variation was due to tracheid length variation within the growth ring.

Spacing appears, from these experiments, to have a highly significant effect, in this plantation, on wood density. As can be seen in Table 7 mean density decreased with increasing spacing. Because of the method of sampling used in these experiments it is not possible to say at what stage of growth this difference becomes apparent. A sampling to take annual growth rings closer to the bark, and rings further from the bark in addition to those sampled in this study, would provide considerably more information on this aspect of wood density variation.

The information presented here does suggest that spacing and canopy closure have an effect on wood density. If this is true, then it could be expected that this variation would normally disappear either, (1) as the more closely spaced trees are thinned, or (2) as the wider spaced trees close canopy.

Acknowledgements

I wish to express my gratitude to all who helped with the research work or in the preparation of the thesis, and a special thanks is due to the Forest Products Department of the Institute for Industrial Research and Standards, Dublin, who so generously placed their facilities at my disposal.

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Trees, Woods and Literature—14

One night Otto Beck left the back cottage door open and made his way to the plantation. He walked along the narrow path until he came to the foot of a high pine tree. It rose to more than a hundred feet, the first fifteen feet bare of any foothold or branch whatsoever. Alongside it grew a laurel, its upper branches caught about the big tree. Otto stuffed the ends of his trousers into his socks as though for cycling and swung himself into the laurel; from there he gained access to the pine tree. Above him now its branches sprouted out with the regularity of rungs on a telegraph pole. He climbed upwards hand over fist, a mariner ascending into the main royal.

As he went higher the branches grew thinner, set closer together. He had to climb round the circumference of the narrowing trunk looking for supports for his hands and feet. When at last he could climb no higher, looking down he saw the meadow set out innocently below him, the beech and the sycamore throwing their heavy shadows before the house. It was a clear night towards the end of July. The house stood in its own dark shadows. The two main bedrooms were on either side of the balcony, divided by the main hall, above drawing-room and dining-room.

From *Langrishe, Go Down* by Aidan Higgins (Calder and Boyars, 1966), reprinted by kind permission of John Calder Ltd.

Langrishe, Go Down is a novel concerning a declining family of middle-aged spinster sisters in the neighbourhood of Celbridge, Co. Kildare in the 1930s. Otto Beck is a native of Bavaria, a perennial student of Philosophy with a Ph.D. thesis which he hopes to finish "in perhaps four years time", sometime forestry worker in Glencree, who becomes involved in a relationship with one of the sisters.

Aidan Higgins was born in Celbridge in 1927, educated at Clongowes Wood, and worked in factories in London before travelling widely throughout the world. He has published short stories (*Felo de se*) and another novel (*Balcony of Europe*, 1972).

Letter to the Editor

The Editor,
Irish Forestry,

Dear Sir,

While recognising the plea from Messrs Carey and McCarthy (letter to Editor, last issue) that "foresters must strive and develop their own analytical procedures which are of relevance to tree growth" and indeed accepting this as a valid long term goal of the soil physicist and chemist we wonder how many Scandinavian or North American foresters would agree with their statement that classification of forest soils on the basis of vegetation is "a system long since recognised as being unsatisfactory". Unsatisfactory to whom, the forest manager or the soil scientist?

If we all possessed the undoubted abilities of Carey and McCarthy and if we all had access to a fully equipped soils analytical laboratory (preferably one which could easily be carried in the pocket or knapsack) we could relate tree growth directly to the complex of soil physical and chemical conditions which influence it. Until then we must use some easily recognised site characteristic as an index of these soil factors. We would again submit that vegetation can be used as such an index.

In the poorly drained peats and gleys on which we have suggested that vegetation provides an index to the growth and fertiliser requirements of Sitka spruce it is very questionable if the tree roots *do* penetrate deeper than the roots of the native vegetation.

We agree that very little of the vegetation in Ireland is unaffected by man's activities. We would, however, suggest that where these activities have altered site conditions sufficiently to produce radical changes in the vegetation then these same changes will also affect tree growth, at least over a large part of the first rotation.

Might we also point out that we did not and still do not suggest that all systems of soil classification are unsatisfactory. To do so would be nonsense. We stated simply that the present system used in Northern Ireland (which is at the level of Great Soils Groups) is and will always be unsatisfactory for forest management. The reason for this is of course simply that the units of classification include too wide a range of variation in the soil factors which influence tree growth. Within a single unit (e.g. surface water gley) the growth of Sitka spruce can range from Yield Class 10 to Yield Class 24.

Only by subdividing the present classification units into sub-units which are related to tree growth can the situation be improved. We suggest that this sub-division should be based on variation in natural vegetation, but we realise that it is not the only way. Our suggested method may lack the scientific sophistication of the approach advocated by Carey and McCarthy but it has two advantages—it is simple and it works.

Yours faithfully

D. A. DICKSON
P. S. SAVILL

Forestry Division,
Department of Agriculture, Belfast.

Notes and News

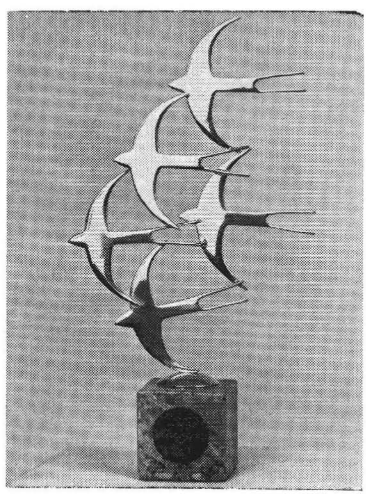
by WOOD KERNE

ABOUT US

I have been informed by the editor of this magazine, a person whose name escapes me, that there have been animadversions, both direct and via his pink questionnaire, (a wholly unnecessary, to my mind, exercise in quasi democracy) on both this column and the picture which heads it. The picture is from a portrait etching which pleases me a lot, and like all works of art it loses much in reproduction. As for the material in the column, it is intended to be literally what it is called: a series of items from various sources, stopping short of gossip, of varying degrees of seriousness, but which might be of interest to members and which they might not otherwise be aware of. And that's that.

AWARD TO FOREST AND WILDLIFE SERVICE

The United Dominions Trust (a finance company) 1975 National Endeavour Award for tourism was given to the Forest and Wildlife Service, Dublin. The citation which accompanied the award was as follows:



"At a time when the preservation of our natural environment and a strong policy of conservation are essential to maintaining Ireland's 'clean' image in the industrial wasteland of Europe, the excellent work of this year's National winner should be fully recognised, not only for its own value but also for the example it displays to the Irish public at large.

'With foresight and imagination, commercial forestry and woodlands have been developed as a major recreational and tourist amenity. Its enlightened attitude to native exploration has proved an appreciable asset to both tourism and the quality of Irish life.

'The 1975 national winner is responsible for 800,000 acres of forest and parks, of which 300 acres are open to the public. These have been developed as tourist attractions, with car parks, picnic areas, resting places—all furnished in good taste, making the best use of timber and other local materials.

'For its very significant contribution to tourism with a service that attracted over 1,000,000 visitors during the year, the 1975 National Award is presented to The Forest and Wildlife Service, Department of Lands."

AN AVERSION TO "SCOTCHMEN"

"I was sorry to see a colony of *Scotchmen* transplanted to the borders of this lake. [Muckross, Killarney]. The *Fir* tree, from its uniform and never varied shape, but ill accords with scenery so wild and natural as that which environs these lakes on all sides; and of all the different species of that ribe, the *Scotch* fir is the worst in every point of view, both as to profit and beauty: being almost the only fir that does not in its growth assume a spiral form,. the quantity of timber it produces, is far less than in those sorts, viz the *Larch, Spruce, Silver,* &c., &c. which measure up to the very top; and the *Scotch* fir has this disadvantage in point of profit, that it takes nearly double the number of years to ripen, though, I will allow, when mature, it may surpass in value the other sorts. As to beauty, in my opinion, *it has none.* All the other tribes, though uniform in their spiral shape, have *rich tints* to recommend them, and, mixed with forest trees, do not hurt the eye of the colourist: but the *Scotchman* is discordant throughout, and its *blue* foliage always offends, and never pleases the eye of taste. I have never seen this tribe look even tolerably well, except when planted together in a large mass, unmixed with any other kind of trees; and then, in particular situations, they have an imposing, though always a *sombre* effect. I was happy however to learn from Mr. Herbert's gardener, that the firs were only intended as *nurses* to the forest trees; and that, having performed their parental office, they would bend to the axe. Every stranger who visits this charming lake, will join with me in the fervent hope that these good intentions may be fulfilled!"

From *Journal of a Tour in Ireland A.D. 1806* by Sir Richard Col Hoare. London and Dublin, 1807. (Supplied by Mr. L. P. O'Flanagan.)

A RARE MANURE

The following is from the British Forestry Commission's Research Report for 1973:

In March 1973, a man's skeleton was found in woodland near Woking, Surrey. There was evidence that he had lived rough in the wood for a short while before his death, and we were asked to help in determining how long ago he had died. From a scar on a pine, and from birch seemingly cut to provide a shelter, it appeared that he went there at some time between the summer of 1969 and spring 1970. Roots from the pine had been growing in the remains of the man's coat for the last two years, and the tree's radial increments for this time showed a remarkable increase, possibly in response to a gruesome fertiliser.

GOBBLEDY—*WHAT?*

"Complex systems that are the means or the objects of research invite the danger of descending into holistic categories of thought. Forest science, particularly in central Europe, presents many vivid and deterrent examples. The holistic model of the "organism of the forest", and its dialectic exploitation by holistic forest ecologists, has caused problems and unnecessary difficulties for many forest geneticists. Probably the periodic prevalence of reductionist ideas and methods in forest genetics is a result of this. This is particularly true in the field of forest tree breeding, which is the practice of biological engineering in forest biology. Today, following the spread of TANSLEY's (1935) ideas on ecosystems, this danger is no longer with us to the same degree. With this development the task of systematic illumination of forest ecosystems has been recognized more clearly and experimental approaches using suitable techniques, methods, and models have been replacing the dialectic models."

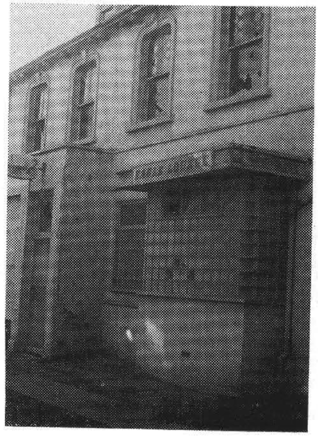
From *Genetics of Forest Ecosystems* by Klaus Stern and Laurence Roche (Springer-Verlag, 1974).

A suitable prize will be offered to any reader who can supply a plausible translation of this into any of the recognised IUFRO or FAO languages, preferably English.

THE "W.K." EFFECT

It was a happy day for science when a Deputy in *Dail Eireann* observed, referring to the continual interventions of another, that he was "up and down like a whore's knickers". This has provided scientists with a long-awaited illumination. Every scientist has encountered that set of data where up-and-down, unexplainable oscillations occur. These can now be ascribed, with incontrovertible argument and ineluctable logic, to "the whore's knickers effect".

TRANSFER TO BRAY



The Research Branch of The Forest and Wildlife Service, formerly dispersed among the garrets and basements of Merrion Street and Merrion Square, have recently transferred to a centralised headquarters at Sidmonton Place, Bray, Co. Wicklow. Bray appears to be a town of declining commercial activity, containing as it does a number of derelict business premises (see photograph). Let us hope that this new influx will go some way towards helping to restore it to its former prosperity.

TO OUR READERS

If you should find any mistakes in this journal please remember that they were put there for a purpose. We try to offer something for everyone; some people are always looking for mistakes.

Review

50 Years of Forestry Research. Forestry Commission Bulletin No 50 (HMSO £1.75).

This bulletin is a review of research work conducted and supported by the Forestry Commission between 1920 and 1970 although the contents separate the 1920 to 1945 period from the remainder.

In his introduction the author refers to the Forestry Act of 1919 marking the beginning of organised forest research in Great Britain. He refers to the considerable volume already written about research topics and he has been guided in selecting and summarising to bring out the main streams and to give as much attention as possible to contemporary thinking and research approach. This then should be a useful bulletin to guide others in their approach to research and to provide the non-research worker with an understanding of the benefits, limitations and probable future course of research.

From the beginning the Commission organised its own research branch to deal with the problems of the growing crop. It felt that other subjects in connection with forestry problems should be referred to the appropriate authority, while the Forest Products Research Laboratory was set up under the Department of Industrial and Scientific Research in 1927 to deal with forest products research. The latter of course also dealt with colonial timbers. The function of the Commission's own research branch was to carry out experiments designed to improve techniques in all branches of practical forestry work, to study the factors of production and to hold a watching brief for new diseases and pests as well as discovering methods of controlling existing disorders. Fundamental research proved a difficult field for the Commission before the Second World War because, although they had the authority to support such research financially if it was likely to yield a direct benefit to forestry, there was no specific Research Council, although the Agricultural Research Council which was set up in 1931 did do a certain amount of work on forest soils and tree nutrition.

The main problems seen in the initial stages were how to apply existing knowledge to the large scale plantings which were then introduced. By and large afforestation objectives were to find the cheapest effective method of establishing a healthy crop rather than to maximise the profitability of the undertaking. Although he refers to the value of R. A. Fisher's work at Rothamsted being recognised at an early stage by the Forestry Commission, the author unfortunately considered that the development of research methods and experimental techniques was not a subject for this particular bulletin. A weakness which he has identified has been that in spite of excellent leadership and communications, progress was delayed because of a lack of development work such as widespread field trials following quickly on indications of promising experimental results.

Then follows a series of chapters dealing with research in the pre-war period under the headings of Nurseries, Establishment, General Silviculture, Species and Provenance, Mensuration, and Protection. These give little information of value in determining how beneficial the research effort has been although they give a few insights into certain basic problems such as restricting nursery research to a special research nursery, with its advantages of better control and experienced experimental staff, but lacking contact with the executive and thereby leaving many field practitioners to discount the results as not applicable to large scale conditions. On this one unfortunately no answer is given on what would appear in retrospect to be the best approach. A rather useful insight is that certain experiments on pruning were few and far between but the field work was valuable in terms of analysis at a much later date.

The chapter dealing with post-war policy indicates that the earlier approach was to be continued with the Commission doing all strictly applied work, and supporting basic work having some bearing on applied forest problems, but not supporting basic work in the forest sciences not related to any specific problem. This latter aspect of research was only covered by the setting up in 1965 of the Natural Environment Research Council which has a Forestry and Woodland Research Committee although of course other committees of it are of interest to foresters such as those on Ecology and Hydrology. A further major policy change introduced post-war was to set up a specific research station with its own Pathology, Entomology and Seed Testing Sections and housing the mensuration specialists while retaining separate silvicultural research in Scotland and England and Wales. The author points out a major difficulty here with his reference to a hint of the confusion of ends and means which has so often bedevilled discussions on kinds of research: sophisticated methods appearing more appropriate to fundamental than to applied research. The American Earl Stone once remarked that you could do pure research with a bulldozer and applied research with a microscope. Unfortunately there is again no comment as to how in that respect a clearer sub-division could have been made or indeed if it was desirable to make such a distinction.

The chapter dealing with organisation and development of research is of interest to show the relative importance attached to different aspects. Thus, apart from the post-war creation of new Departments of Pathology and Entomology as mentioned above, the first new section was Genetics. It is interesting that there was some opposition to this on the ground that more was to be gained by attention to seed supply at the species and provenance level but the comment is made by the author that organisation of seed supply remained weak over much of the post-war period resulting in the loss of a good deal of productive capacity. There is an apparent inference from this that the Commission would have been better to have concentrated more on seed and provenance and less on genetics in the 1950s. A separate Soils Section was established in 1963 and an Ecological Section in 1964 while in the early post-war period the Scottish silviculturalist was given responsibility for North England thereby giving him the bulk of the work on upland afforestation. During the post-war period the Mensuration Section evolved beyond recognition and one of its sub-sections, Statistics, was expanded into a separate research section; further additions were working plans plans and a new section on Forest Economics. However in 1960 management left research to become a Headquarters function and in 1966 management, work study and machinery research was incorporated in Headquarters Management Services Division. In the whole of the post-war period there was also some addition at Headquarters of specialist sections which were concerned in part at least with research such as machinery development, first introduced in 1949, utilisation in 1950 and work study in 1954.

Reference is also made in this chapter to the disadvantages of Alice Holt as a central research station. Apart from the fact that it was considered remote from Scotland where much of the effort was required there was an obvious change in approach with silvicultural research calling for some laboratory facilities and then for more laboratory staff etc., and ultimately this led in 1970 to the opening of the Bush Research Centre near Edinburgh. Reference is made in the bulletin to its favourable situation close to other research organisations such as those dealing with hill farming, plant breeding and the University Department of Forestry and Natural Resources. Although the Commission had earlier decided against too close a link between its own research work and that of any other institutes including those dealing with fundamental aspects there is no comment by the author as to how far this move has been a good or a bad thing. He does however indicate that the next decade will see a process of adjustment between the Commission and the Natural Environment Research Council, and in many ways it is regretted that a research council concerned with forest science arrived on the scene so late in the day. Is Wood saying that it would have been better all along to have had such close links with another basic research institute? Indeed the whole question appears to be one which the Forestry

Commission has found almost impossible to solve, especially as one notes that they set up their own section dealing with tree physiology based in Edinburgh rather than let this be handled within the general confines of the Natural Environment Research Council.

Wood comments that the research programme has largely been initiated by research. It has been the main item for discussion at an Annual Research Conference and has been presented to the Research Advisory Committee for general comment. This Advisory Committee is a small Committee with close ties to the Imperial (now Commonwealth) Forestry Institute in Oxford, Kew, Rothamsted, Macauley Institute, Forests Products Research Laboratory, and a Professor of one of the other Forestry schools. Wood suggests that this has been a useful committee but it appears that his thinking has been influenced by members' help in various aspects in which members of the Advisory Committee were themselves specialists. In this general context it is of interest that the original discussions were obviously based on detailed lists of work to be done but that this has now changed to summaries setting out directions of work under major project headings as far as possible. In this way it is obviously easier to control the whole body of research and link various disciplines one with another.

Although Wood once more commends the research station for its use of statistical techniques for design and analysis of experiments and surveys and for its lead in computerisation and that this has proved its value in eliminating errors, areas of boredom etc. and enabled the computation of complex calculations, he does suggest that in a research establishment Parkinson's law operates very much as far as computers are concerned. He is not prepared unfortunately to comment on whether an establihsment is better to own its own computer or have access to larger central installations.

A general comment is given in the chapter on organisation and development that in the post-war period much more financial support was given to grant-aiding and co-operation in research. Various types of arrangements from specific aid for individual projects to paying for staff stationed at other institutes etc. have been tried and in the absence of other comment one must assume that they have all been equally effective. There has of course been an end to the Commission grant-aiding items which are not of direct application, which were considered to be completely the responsibility of NERC once it was set up. The only other general reference to the cost of research over this 50 year period is in the very first chapter on pre-war policy when it is stated that the annual total expenditure increased from £6,900 per annum to £18,000 pre-war (this figure included grants to institutions), and that by 1969 research expenditure was £873,000.

Unfortunately it is not clear if the latter is only direct Forestry Commission research or whether it includes grants to other institutes for work related to immediate problems or work related to non-specific problems.

Forestry Commission work on tree seed was largely to improve laboratory testing methods on germination etc. and the comment is made that it had a large share in the economics in seed purchase which became increasingly apparent in the 60s.

The main interest in the chapter on nursery nutrition is that although this topic was obviously closely related to day to day operations research was passed to a sub-committee of the Research Advisory Committee and much of the work was done by a straight financial grant to Rothamstead. The comment is made that research failed to show advantages for rotations, fallow crops, cover crops etc. but in general this section shows the value of new thought in solving intractible problems. Although seed bed weeding costs came down by 80% it has been difficult to put a value on the work on herbicides. Again the techniques of using tubed seedlings or the "Finnish Roll" are not evaluated. Reference is made to the study of minor species on some 500 scattered sites using production profitability as a criterion. Direct species research work and trials have however largely been concentrated on poplar and elm "because of their importance" outside Forestry Commission operations and because of Peace's interest in the importance of specific diseases. Reference is made to the importance of exposure in limiting afforestation.

The nutrition of forest crops has been looked at largely in England or in a specialised manner on the Culbin sands in Scotland. The mobilisation of nitrogen in forest soils remains one of the great problems of cool temperate regions but the comment is made that it is probable we have approached the limits of what can be done by manuring in the establishment of the crop. Reference is made to the virtual total use of laboratory analysis to help in assessing projects for refertilisation of pole stage crops but does this not leave the impression that the art is sufficiently sophisticated for all situations?—hardly the case in many of the situations one finds in the field.

The chapter on cultivation and drainage research shows the concentration on heath type sites and interestingly comments that treatments regarded as uneconomic when the experiments started now show valuable results, and the question of evaluation of these has to be reopened. The truism is made that "the evaluation of drainage effects is likely to prove a compicated business' but no hint if given of how it might be attempted.

Although regeneration and ıehabilitation are going to become more and more important items in the future research has been rather limited.

Further developments in the field of weed control are expected. The earlier work on pruning has raised questions of the effect on increment and dominance but no answers or opinions on these effects are given.

Work on composition and stability is recorded as possibly suffering from a lack of definition between the job of the mensuration and the silvicultural specialists but no conclusions can be reached as yet on mixtures, irregular crops etc. being any more stable than others. The need to look at under-planting for change of species is mentioned.

The section on provenance and breeding gives some interesting comment on all the main species and on the problems associated with vegetative reproduction. Of particular interest is the statement that it will be a slow process to improve Sitka spruce by conventional breeding methods and the difficulty of linking characteristics such as density with trees identified visually as plus trees is touched in passing.

The brief history of soils research is illuminating in that although help was given to many outside organisations with international reputations such as Oxford University, Macauley, Rothamstead, Nature Conservancy, and Edinburgh University the Commission opened its own soils laboratory in 1955 enabling analytical and instrumental studies of soils to be made. The basic reasons for this change are not given at all. Although earlier worries about the problems of mor formation have largely disappeared the bulletin is refreshingly frank about the lack of benefit to date from the biological as opposed to the nutritional approach, while recognising that large stores of unavailable nitrogen posed problems for the future. The comment that uneven distribution of nutrients in the profile is a problem is hardly justified by itself.

The chapter on protection laments the limitation of research effort on pests and diseases but then proceeds to give an excellent summary of the control operations which have been developed and put into effect in the past 50 years. Many of these have of course broken completely new ground such as the use of *Peniophora* for *Fomes* control and the virus suspension for *Neodiprion* control. The *Fomes* story indeed highlights the value of objective basic research which, because the method of infection had been identified, enabled a quick solution to be found when the economic problem arose. The summary also gives useful comment on the likelihood of certain insect and other pests becoming a major problem or where natural population collapse seems to be a general feature.

Chapters are included on mensuration, management, economics, operational research, development and publications because they were at one time or another part of the Research Branch. These give a good summarised history of the evolution of these topics in the organisation of the Forestry Commission but still leave "as a matter for convenience" the question as to how far they should be associated with management or with research. A valuable point is however made that it may be useful to bring in operational research techniques at the outset. Many workers finding difficulty getting through the mass of paper will welcome the suggestion that documentation may have been over-emphasised and that in future there should be a concentration on document keys.

It will be seen from the above that the contents are very patchy in relation to indicating contemporary thinking on the many different problems which will arise for forest research. Even though the author in his concluding remarks says "any attempt at a general evaluation would be over ambitious" it is unfortunate that references to the cost of the research programme are generally lacking. The bulletin is very sketchy on the research approach and the author has often been content merely to list problem questions. There are great difficulties for those concerned with the organisation of all Forest Services in determining who should do research, how much should be spent on it, priorities of work etc. These are also of interest to all practicing foresters who want to be sure that they are backed up by good cost-effective research with quick and easy access to up-to-date results. With the forward looking approach of the Forestry Commission on so many fronts what a pity that the opportunity was not grasped on this occasion to give more answers, however personal and tentative, rather than restate the problems. Perhaps your reviewer was expecting too much but he is certainly left with the impression of a handsomely and expensively produced document eminently readable but adding little to the solving of the basic research programme problems. Society members will however find it interesting reading.

W. H. JACK

Other Publications received

FORESTRY COMMISSION PUBLICATIONS

Forestry Mensuration Handbook, by G. J. Hamilton. Booklet No. 39, £4.00.

Part I. General aspects of measurement

Part II. Measurement conventions

Part III. Measurement of felled timber.
(Gives procedures for timber lengths, sawlogs, smallwood, pitwood, stacked timber, weight.)

Part IV. Measurement of standing timber.
(Gives procedures for single standing trees, standing sales, inventory and valuation, piece-work payment, thinning control.)

Part V. Miscellaneous
(Includes sampling, plot sizes, relascope, bark, etc., etc.)

Part VI. Tables.
(Gives tables relevant to the procedures described in parts III and IV.)

Chemical Control of Weeds in the Forest, by R. M. Brown. Booklet No. 40, 90p.

Seed Orchards, by R. Faulkner. Bulletin No. 34, £2.30.

Report on Forest Research 1975. £.185.

Fifty-Fifth Annual Report and Accounts 1974-75. £1.65.

FOREST RECORDS

101 *Red squirrel,* by A. M. Tittensor. 42p.
102 *Three forest climbers: Ivy, old man's bread and Honeysuckle,* by A. F. Mitchell. 23p.
104 *Towards integrated control of tree aphids,* by C. I. Carter. 50p.
105 *Experiments with insecticides for the control of Dutch elm disease,* by T. M. Scott and C. Walker. 70p.

LEAFLETS

61 *Tubed seedlings,* by A. J. Low and J. S. Oakley. 30p.
62 *Ultra low volume herbicide spraying,* by E. V. Rogers. 35p.
63 *Fertilisers in the forest: a guide to materials,* by W. O. Binns. 35p.

Society Activities

THE QUESTIONNAIRE

N. O'CARROLL

THERE were 37 completed questionnaire forms returned at the time of writing. Of those, 30 were from technical and 7 from associate members, Twenty-seven respondents signed their names. All the replies were helpful, and while some were critical they were constructively so; there were no purely negative or abusive replies.

Question 1

This asked readers to assign each class of material in the journal a mark ranging from 1 (excellent) to 4 (poor). There was also a category for 'no opinion'. The only class for which a significant number (8) expressed 'no opinion' was that of obituaries, presumably a tendency to extend the '*De mortuis* . . .' principle to include all references to the deceased. The averages of the marks received by each class of material were as follows:

Articles	1.8
Abstracts	2.2
Cover photograph	1.9
Editorial	1.5
Reports of annual study tours	2.6
Reports of day meetings	2.2
Reports of lectures	2.3
Reports of meetings, symposia etc.	2.9
Notes and news	2.4
Obituaries	2.0
Reviews	2.2
Trees, woods and literature	2.1

Question 2

Readers were asked to list the most interesting/useful and least interesting/useful articles printed in the last seven volumes. The nominations varied very widely, but the top six in the list of most interesting and most useful were:

Joint first: Coniferous growth and rooting patterns on machine sod-peat bog (cutover) at Trench 14, Clonsast, by M. L. Carey and T. A. Barry. (Vol. 32, No. 1, p. 18).

The influence of tree spacing on Sitka spruce growth, by W. H. Jack (Vol. 28, No. 1, p. 13).

Joint third: Hydridisation among deer and its implications for conservation, by Rory Harrington. (Vol. 30, No. 2, p. 64).

Origins and distribution of peat types in the bogs of Ireland, by T. A. Barry. (Vol. 26, No. 2, p. 40).

Joint fifth: Some forestry problems in the European Community, by X. Le Chatelier. (Vol. 29, No. 2, p. 4).

Spruce growth rates on drumlin soils, by L. P. O'Flanagan and M. Bulfin. (Vol. 27, No. 1, p. 4).

Nominations for least interesting/useful were much more scattered and it is gratifying to note that no single article was outstanding in this respect.

Question **3** asked for views on the kinds of articles which members would like to see more of and less of. Generally the demand is for more articles on general silviculture and forest management, and fewer highly technical articles which are of interest to a limited readership only. I would agree fully with those demands. The main difficulty with the first kind is finding the people both able and willing to write them (A few specific suggestions by respondents will be followed up). In the case of the second kind we must take the view that, in the absence of more appropriate vehicles of publication in Ireland, the journal is carrying out the objects of the Society in printing them.

Question **4** asked what should be the aims of the journal, and for opinions as to how well if at all it was succeeding. The table shows the number of opinions recorded for each option:

Summary of replies to question 4

	Should it be?		How successful?		
Possible aim	Yes	No	Very	Moderately	Not at all
Inform members	36	0	11	16	1
Educate members	30	1	11	14	1
Print research results	25	0	13	9	3
Entertain/amuse	12	14	2	8	3

It would appear from the last line that we Irish Foresters tend to be a somewhat puritan lot, or else we like to keep our work and play very sharply separated.

One respondent who thought that the journal was quite unsuccessful in all the aims added that this was because 'they' didn't read it. If that were so of course the journal would have to accept its share of the blame.

There were a number of other functions suggested, the most popular being a correspondence section (please do write to us!) and more attention to private forestry.

Question **5** asking for general comments cannot easily be summarised. The replies in general tended to reflect the opinions expressed in the replies to the other questions, and the overall tone could be said to be one of qualified satisfaction. The comments here and under 'general remarks' will give plenty of food for reflection by the present and future editors.

MEETING IN FERMANAGH

Over 70 members were present at the Northern Region meeting in Co. Fermanagh on 30 April 1975. It was organised primarily to see a demonstration of aerial fertilizing by helicopter at Lough Navar Forest, laid on by Central Helicopter Services Ltd. who were carrying out a contract for the Northern Ireland Forest Service. Unfortunately the day was too windy for normal flying to be carried out safely but a special short demonstration was provided. Stops were also made for explaining detailed planning, organisation and quality control procedures which are necessary for a successful operation.

Some time was spent in the morning visiting Belmore Forest and surrounding areas, where fertilizer prescriptions for Sitka spruce planted on gleyed soils of different fertility levels were explained. (Details appear in an article by Savill and Dickson in *Irish Forestry* Vol. 32 No. 1 (1975).)

The party was also able to see some of the recreational facilities provided in the forests of this very attractive part of Fermanagh, the most impressive of which is the viewpoint at Lough Navar Forest overlooking lower Lough Erne.

Many staff of the Northern Ireland Forest Service contributed towards making this a very enjoyable and worthwhile day. The Society's thanks are extended to them all, but in particular to Mr. W. J. Wright in whose District the tour took place.

P.S.S.

MEETING IN OFFALY

About 90 members turned up at Edenderry Forest on Monday 22nd September 1975, at Derrycricket property, for a field day organised and presented by the Soils and Nutrition Section of the Forest and Wildlife Service's Research Branch.

The morning was spent looking at a series of experiments on a fen peat site which was highly deficient in potassium. Potassium deficiency symptoms and the response to potassium fertilisation were demonstrated, and an experiment which showed that, at least in the early years, spot application of potassium fertiliser gave better results than broadcast application, but it was suggested that this would change when the tree roots developed over the whole ground area. In an experiment on combined effects of potassium and phosphorus there was a slight, though stastically significant, and as yet unexplained, reduction in growth due to the application of rock phosphate. Another experiment demonstrated that potassium could be supplied with equal efficiency either as the chloride (muriate) or as the sulphate, although the former is considerably cheaper.

After lunch the group moved to a machine cutaway area in Clonsast Bog (Trench 14) where forest experiments have been going on since 1955. A species trial indicated yield classes well into the twenties for both Sitka spruce and lodgepole pine at nine years, although the spruce was not as happy where the peat was deeper. A twenty-one year old plot of *Pinus radiata* on deep peat showed the great potential of that species, as indicated by its prodigious height growth, but not yet attainable because of poor survival at establishment and subsequent deaths from unknown causes. A thinned plot of Japanese larch was seen, the first forest produce to be harvested from machine cutaway bog in Ireland and the final stop was at the stand of grand fir whose high yield class, and extraordinary ability to root deep into a calcareous subsoil has already been described in this journal. (Vol. 32, No. 1, 1975, p. 18.)

N.OC.

ACKNOWLEDGEMENT

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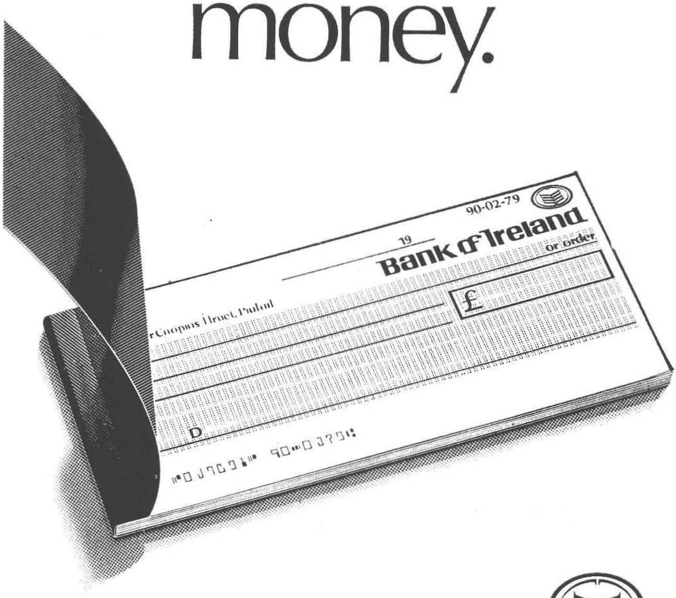
Ernest **JOHNSTON,** O. V. **MOONEY** and Michael **O'BRIEN** photographed at a Society study tour.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