Forestry Commission Bulletin



43

# Nursery Practice

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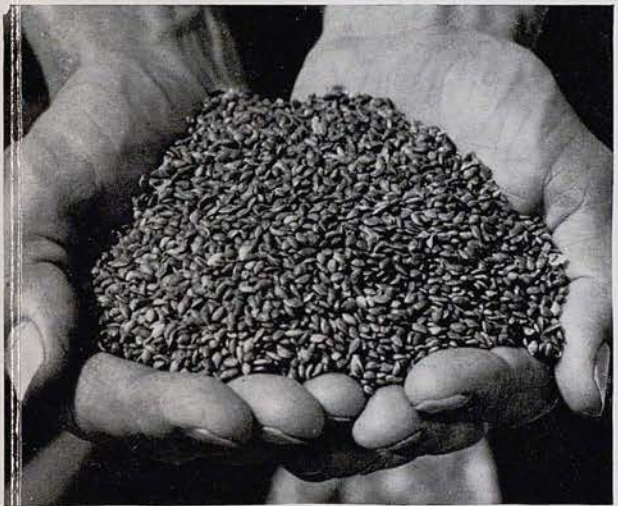
J R Aldhous



The front cover shows conifer seeds, one-year-old seedlings of Sitka spruce, and a general view of a Forestry Commission nursery.

FORESTRY COMMISSION BULLETIN
No. 43

# Nursery Practice

By J. R. ALDHOUS, B.A.
*Forestry Commission*

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## FOREWORD

This Bulletin summarises results gained from the extensive programme of experiments and enquiries carried out by the Forestry Commission's Research Division, from its inception in 1919 until the year 1970, together with the practical experience obtained in the large-scale raising of planting stocks for the national afforestation programme.

FORESTRY COMMISSION

*March* 1972

## PREFACE TO 1975 REPRINT

The demand for this Bulletin has been greater than anticipated and stocks have become exhausted much sooner than expected. Although nursery techniques develop continuously, the short time since this Bulletin was written means that the items requiring amendment are relatively few in number. It has therefore been possible to reprint unchanged. The attention of the reader is however drawn to certain aspects that have undergone significant changes since 1972.

The substance of Chapter 7 "Seedbeds", paragraph 7.61 on "Production of seedlings in tubes" is now covered in greater detail in Forestry Commission Bulletin No. 53, entitled *Production and Use of Tubed Seedlings* (HMSO, 1975, £1) and the reader is advised to consult this.

A similar technique of raising seedlings in Paperpots, paragraph 7.62, has developed to a stage where it is now in use for the production of Corsican pine for planting at Thetford Forest in East Anglia. Compared with the tubes this process produces a larger seedling in a larger container and is satisfactory for planting on sandy soils. Unlike the tubelings on mineral soils, frost-lift has not proved to be a problem.

Costs of production of seedlings in Paperpots are similar to those of transplants in the open nursery. Decisions on the extent to which this technique is adopted therefore depend on other factors than the cost of plants. There are substantial management advantages in growing nursery stocks on the short cycle required, namely 4–5 months, so that plant supply can be more closely matched to demand. The time of planting is much less critical and can in fact be carried out at any time of the year. The disadvantages are that this container-grown stock is smaller than transplants and may require a longer period of weeding on weedy sites and may be more susceptible to mammal and insect damage.

R. E. CROWTHER
*Silviculturist, South,*
*Forestry Commission,*
July 1975

## ACKNOWLEDGEMENTS

This Bulletin has been prepared, following stimulus and encouragement from a Nursery Management Committee under the chairmanship of the late Mr J. Q. Williamson, by Mr John R. Aldhous, the Head of the Silviculture (South) Section of the Forestry Commission's Research Division.

Many people on the Commission's Research staff have provided material for various chapters, especially Dr W. O. Binns, Head of Soils Section (Chapters 3 and 4); Mr G. Buszewicz, Head of Seeds Section (Chapter 6); the late Mr W. G. Gray, Head Forester at Kennington Research Nursery, near Oxford (Chapters 7, 8 and 12); and Mr D. Bevan, Head of Entomology Section (Chapter 11). Their help, and also that of Mr I. A. Anderson, Principal Photographer, Mr R. M. Brown and Mr P. W. D. Daborn, has been warmly appreciated.

Comments and useful criticisms have been received from many colleagues in all branches of the Forestry Commission. Their value is indicated by the fact that very few such comments have been discarded as being of little worth.

Miss Blanche Benzian of Rothamsted Experimental Station, Harpenden, Hertfordshire, has also been an unfailing source of informed comment and help, both through her own invaluable publications and through personal contact.

All the photographs have been drawn from the Forestry Commission's official collection, and carry appropriate reference numbers.

Figure 1 is reproduced by kind permission of the United States Department of Agriculture. The remaining figures were drawn by Forestry Commission staff.

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# Chapter 1
# NURSERY POLICY AND PLANNING

Forest nurseries are an essential part of forestry in Britain. During the twenty years to 1970, a total of some 200 million plants have been sent each year into privately and nationally owned forest. While production methods may change, forest nurseries are certain to continue to be the source of new trees for future forests, for although natural regeneration is the traditional means of restocking in less intensively managed natural forests, in Britain the introduced species dominate commercial forestry. Felled plantations are likely to be replaced either with more productive species, or with strains of the same species but of improved quality or vigour; such improved stock has to be raised either in an open nursery, or possibly by one of the more intensive methods described at the end of Chapters 7 and 8.

In the last twenty years, while the number of plants produced in forest nurseries has remained steady, the costs of nursery production have dropped relative to other costs. In 1945, the cost of planting stock was roughly a quarter of the total cost of establishing a new plantation, but by 1967, the cost of planting stock was only about ten per cent of the cost of establishment. This major reduction in relative costs has been the result of intensive research and development in all aspects of nursery production but especially in soil fertility, plant nutrition, weed control and mechanisation.

It is hoped that this bulletin will provide a ready reference for the nursery owner or manager giving guidance on most points of practice concerning the raising of young trees for planting in the forest.

No attempt is made to describe practice in raising ornamental varieties of trees or the production of large trees for planting as specimens or in landscape work.

*N.B. Throughout this bulletin, metric quantities follow their imperial measure equivalents, in italics, after an oblique stroke.*

## 1.1 Policy

Forest nurseries may be managed either to produce plants for sale on the open market, or to produce plants to meet a previously known commitment, whether a long-term planting programme or a contract. Many nurseries produce for both outlets, and thereby have the income and security from regular contract sales as well as the opportunity to increase sales and profits by selling the rest of their stock on the open market.

This bulletin is written on the assumption that the policy of the nursery manager is to raise good quality plants at the lowest cost. Little allowance is made for the estate owner who wants to raise a few plants for his own use on ground that may not be well suited to the growth of young forest trees. Such owners are recommended to follow the recommendations in this bulletin as far as they apply; the stocks raised will probably grow more slowly while in the nursery, but should be suitable for forest use. They will probably have cost more to produce than in a better nursery, though not necessarily more than the purchase price from a reputable nurseryman. The owner will have the convenience of having his plants available whenever he can lift them, and also the satisfaction of seeing them grow.

### 1.11 Whether or Not to Have a Nursery

The most important factors determining whether it is likely to be profitable to have a nursery are, firstly, whether a suitable site is available, and secondly, how many plants will be required and over what period. It is not economical to start a nursery for less than a regular annual production of 25 000 planting stock.

Both seedlings and transplants are normally raised in a nursery. However, if the available skilled supervision is limited, seedlings can be purchased, and the nursery restricted to the raising of transplants, thereby avoiding the more technically difficult part of nursery work.

### 1.12 The Nursery Site

The features which a good nursery site must possess are discussed at length in Chapters 2 and 3. If any of the more important of these are ignored, costs of production are likely to be higher and growth slower than on good sites.

### 1.13 Size of Nursery

The simplest guide to size in relation to output is that about one acre of nursery (gross area, including paths, fallow etc) is required for every 70 000 to 100 000 plants (i.e. forest planting stock) to be produced. *The equivalent metric quantities are: one hectare for* 180 000 *to* 250 000 *plants.*

*Seedbed Area.* For every unit area cultivated, approximately 60 per cent is sown; the remaining area is taken up by alleys between beds. The density of stocking of seedbeds may range from 200 to 1200 per square yard/*240 to 1400 per square metre* according to species and season, but columns 10 and 11 of Table 23, pages 63 and 64 give average stocking in good nurseries.

*Transplant Area.* Where there are no alleys separating every 5, 6 or 7 lines, 98 per cent of the gross cropped area can be taken as the net area under transplants. Where strip lining out is practised using the 6 ft 4 in/*2 m* (Paterson) board and 18 in/*45 cm* alleys between strips, the net area is 80 per cent of the cropped area. Where transplants are in beds separated by alleys, the beds consisting of between 5 and 7 long lines of transplants, the net area is approximately 60 per cent of the cropped area.

The relationship of spacing of plants in and between rows is shown in Table 27, page 76. When planning nursery areas it is advisable to allow for 70 per cent survival in the lines.

*Fallow Land.* Between a quarter and a third of the cultivated area at least should be fallow or green-cropped at any one time. There are many calls on fallow land. They include: summer lining-out of rising two-year-old plants or plants from cold store; the completion of a substantial part of the lining-out programme before Christmas (some foresters try to complete a half by this time); throwing up of seedbeds in the autumn or winter in preparation for spring; holding over for another year substantial numbers of surplus seedlings or transplants.

If it is anticipated that there will be regular and substantial calls on fallow ground for two or more of these reasons, the proportion of fallow land should be increased to 40 per cent of the total cultivated area. When planning a nursery, it is far better to err on the generous side with the allowance of fallow land; the cost of maintaining surplus fallow is small, and is a worthwhile insurance.

*Uncultivated Ground.* The area occupied by permanent roads, buildings, hedges, dumps of hopwaste and other permanently uncultivated areas within the nursery perimeter, taken together, usually amount to between 20 and 30 per cent of the total nursery area. The higher figure should be used in planning if machinery is to be employed in the nursery; this will allow for the additional space required for machines to manoeuvre. Provision should also be made for an area where liquid used for cleaning spray machinery etc can safely be handled.

## 1.2 Planning Production

It is essential to appreciate that forest nursery work requires to be planned out, well in advance, by a person well experienced in *forest* nursery work, rather than in some kindred skill. The benefits of such experience and skill can be expected not only in any advance planning but also in the execution of plans and in timing them in relation to the day-to-day conditions in the nursery.

Nursery planning, whether of the requirements of man-power and machines or of plants and materials, can be simplified if records are available from which can be estimated:

(a) the annual demand for planting stock, by species, provenances, age and size;

(b) the year-by-year out-turn from seedbeds and lines;

(c) the cost, labour and time requirements of various operations.

Such records should assist the nursery manager to determine his future programme and in particular give him some idea of what margins of error he should allow for seasonal variations in yield.

## 1.3 Records

Nursery Records can be divided into:

(a) *Plant production:* Details of seed origin; amounts of seed sown; seedlings lifted; plants lined out, forest plants lifted, poplar or other cuttings inserted and rooted plants lifted.

(b) *Cash expenditure:* (i) consumable stores including fertilizers, seedbed cover, seed, fuel and lubricants, etc. (ii) capital expenditure—buildings, equipment and machines etc. (iii) wages and salaries. (iv) overheads—heating and lighting, insurance, interest on capital invested in the nursery etc.

(c) *Operations:* Details of those operations and conditions in the nursery which may affect yields and help comparison of one year's results with another. These may best be kept in a diary.

The first and most important thing to decide is what purpose any given records are to fulfil, e.g. to provide a guide as to the financial and technical efficiency of the nursery. Records collected without a clear idea of their purpose are quite likely to omit the vital point required in a later study.

### 1.31 Stocktaking

This is a most important operation which normally falls due in late summer. Over-estimates of number of plants can lead to over-selling and subsequent embarrassment. Under-estimates may lead to wastage and loss of profits.

The main problem with stocktaking is that estimates of what will be available, very often have to be made during August at a time when many plants have still to put on a substantial part of their growth. The amount of this late growth can often be critical in determining the size, grade or usability of the plants concerned.

The system of stocktaking in Forestry Commission nurseries has recently been changed to take account of modern statistical sampling methods. Full instructions for the system are set out in Appendix I. This system is designed primarily for large blocks of seedbeds or transplants and gives values to within 10 per cent or 5 per cent of the actual number of stock, provided the forester has correctly estimated the percentage of usable stock.

This system may well not suit many nurserymen, especially those with nurseries containing small breaks of seedbeds or transplants. However, two features, the seedbed sampling grid one-tenth of a yard/*0.1 metre* wide and the smaller counts in long lines of transplants, can be recommended for any system of stocktaking, as they both reduce the errors of counting.

### 1.32 Labelling of Plants in the Nursery, and Nursery Plans

It is of utmost importance to be able to assure purchasers that the origin of plants is as stated in catalogues. Any system of naming must be foolproof, and, if the nursery is so situated, vandal-proof.

Each lot of seed sown and of plants lined-out must be labelled as soon as practically possible, showing at least the species and an unambiguous name or number through which the origin of the seed or seedlings can be traced. It is useful to add the actual origin itself and the date of sowing or transplanting. The Forest Seed Association (see section 6.7, page 52, for details) has designed suitable labels.

In addition, a map or plan must be prepared, showing the position of each lot of seedlings or transplants so that should a label be lost or displaced, there is an undisputable record as to where any new label should go.

All these efforts will be wasted if similar care is not exercised to maintain the identity of plants at all stages during handling and despatch.

## 1.4 Sale of Plants

Plants may be offered for sale by advertising in any of the forestry journals and in other journals reaching potential customers. At the same time, a price list or catalogue giving details of the species, origins, sizes and prices of plants that are available must be ready by at least mid-summer. The list or catalogue has to be prepared in advance of the results of stocktaking and has to be made on the assumption that plants will grow as expected.

### 1.41 Horticultural Trades Association Clearing House

The H.T.A. have, for the last few years, operated a scheme whereby nurserymen with unsold stocks notify the Secretary of the Forest Nursery Section of the H.T.A. Potential purchasers can obtain trees notified to the Clearing House, through any nurseryman who is a member of the H.T.A., or they may approach the Clearing House direct. The address of the Secretary of the Clearing House of the H.T.A. (in 1972) is: Mrs M. Limbert, H.T.A. Clearing House, 2 Green Acres, Kirkhill, Morpeth, Northumberland.

### 1.42 Forestry Commission Surplus Plants

The Forestry Commission periodically has plants surplus to its needs and may sell these to any willing purchaser. Enquiries should be made to any Conservancy Office. (Addresses in Appendix II, page 144).

### 1.43 Samples

Any enquirer wishing to purchase any substantial quantity of forest plants should either see them in the nursery or should ask for samples.

The nurseryman should welcome requests for samples, and should take pains to include plants of the full range of sizes in the lot in question; if this is done, much unprofitable argument between the nurseryman and purchaser about whether plants sent were as advertised, can be avoided. A sample should consist of at least 10 transplants, or 25 seedlings.

The purchaser should bed out sample plants so as to be able to compare them with the full consignment when received.

## 1.5 Quality of Plants

Quality in the context of this bulletin means the fitness of plants for planting in the forest; given equal treatment, good quality plants have a better chance of becoming established and getting away to a good start than poor quality stock. Attributes of quality include:

- Height
- Sturdiness, i.e. ratio of height to the diameter at the root collar
- Root formation and root/shoot ratio
- Foliage and branching (including persistent, strong leading shoot)
- Condition

(See also section 1.7, page 5.)

### 1.51 Height

Plants sent out for planting in the forest should exceed the minima given in Table 1. Height is here defined as the distance from the root collar to the bud of the leading shoot.

### 1.52 Sturdiness

The diameter at root collar of plants of a given height depends very much on the amount of growing space they have been given. However, the range of possible root collar diameters for a given height does differ from one species to another, and the commonly planted forest species can be grouped into the four stem diameter classes shown in Table 1. Species in Class I are the most sturdy for a given height, while those in Class IV are slenderest.

TABLE 1

MINIMUM HEIGHT AND STEM DIAMETER CLASS OF TRANSPLANTS BEING SENT FOR PLANTING IN THE FOREST

| Species | Minimum height inches | *cm* | Stem diameter class |
|---|---|---|---|
| CONIFERS | | | |
| Scots pine | 6 | *15* | I |
| Corsican pine | 4 | *10* | II |
| Lodgepole pine | 6 | *15* | II |
| European larch | 9 | *22* | III |
| Japanese larch | 9 | *22* | III |
| Hybrid larch | 9 | *22* | III |
| Douglas fir | 9 | *22* | III |
| Sitka spruce | 6 | *15* | III |
| Norway spruce | 6 | *15* | I |
| Noble fir | 6 | *15* | I |
| Grand fir | 6 | *15* | I |
| Western hemlock | 9 | *22* | IV |
| Western red cedar | 9 | *22* | II |
| Lawson cypress | 9 | *22* | III |
| BROADLEAF SPECIES | | | |
| Oak | 9 | *22* | I |
| Beech | 9 | *22* | II |
| Ash | 12 | *30* | I |
| Sycamore | 12 | *30* | I |
| Sweet chestnut | 12 | *30* | I |

TABLE 2

STANDARDS OF STURDINESS (MINIMUM STEM DIAMETERS FOR GIVEN HEIGHTS)—FOR TRANSPLANTS SENT FOR PLANTING IN THE FOREST

SPECIES GROUPED BY CLASSES AS SHOWN IN TABLE 1

| Height not exceeding | | Minimum stem diameter at collar | | | |
|---|---|---|---|---|---|
| | | Class I | Class II | Class III | Class IV |
| inches | *cm* | mm | mm | mm | mm |
| 6 | *15* | 2.5 | 2.5 | 2.5 | 2.5 |
| 9 | *22* | 4.0 | 3.0 | 2.5 | 2.5 |
| 12 | *30* | 5.0 | 4.0 | 3.0 | 2.5 |
| 15 | *38* | 6.5 | 5.0 | 4.0 | 3.0 |
| 18 | *45* | 7.5 | 6.0 | 4.5 | 4.0 |
| 21 | *53* | 9.0 | 7.0 | 5.5 | 4.5 |
| 24 | *61* | 10.0 | 8.0 | 6.0 | 5.0 |

Table 2 gives standards for minimum root collar diameter for various heights of trees.

### 1.53 Root Formation and Root/Shoot Ratio

In spite of many attempts, it has not been possible to find any simple objective non-destructive assessment of root quality or root/shoot ratio. Nevertheless some guidance can be given. For all species, the object is to produce plants with a well-branched root system carrying many short fibrous rootlets. Transplanting is one of the best ways of achieving such a root system, and particular care must be taken, when lifting, to leave behind the least amount of fibrous root, especially when handling those species which develop fibrous roots less freely.

Roots must not have been stripped of bark.

The bigger and better developed the main stem and side shoots are, the larger and more fibrous should the root system be. A plant with a moderate size main stem and good root system is more likely to become established quickly than a plant with a similar root system but larger top.

### 1.54 Foliage and Branching

Evergreen species should carry at least the current year's foliage. All species should be well branched. Plants which have inadequate branches are likely to be spindly and may be rejected according to the standards set out in Table 2. Conifers should have a clearly defined single terminal bud or leader, while hardwoods should have a well developed central main stem.

### 1.55 Condition

Plants should be free from visible disease or physical damage. They should be a normal colour and not a colour indicating a nutrient deficiency. (Seasonal bronzing of species like Western red cedar is not a defect).

Plants must not have been subject to waterlogging in the winter prior to lifting as this may kill the roots without affecting the foliage. Such waterlogged plants may start to flush shortly after planting but thereafter the tops soon die.

Plants must not be allowed to dry out in the period between lifting and planting in the forest, nor should they have become heated while in store or in transit. See also Chapter 9, page 86.

## 1.6 Names and Ages of Plants

The names given in Appendices VII and VIII, pages 162 to 164 are used throughout this bulletin. Column 2 of each appendix gives current botanical names.

### 1.61 Type of Plant—Definitions

(in accordance with British Standard 3936).

*Seedling:* Any plant remaining undisturbed since sowing.

*Transplant:* Any plant which has been transplanted one or more times in the nursery.

*Undercut Seedling:* A seedling which has had its roots severed at a predetermined depth in the seed bed.

*Undercut Transplant:* A transplant which has had its roots severed at a predetermined depth in the transplant line.

*Rooted Cutting:* A plant raised from a cutting and remaining undisturbed since insertion.

*Stumped Plant:* A plant cut back to just above ground level following transplanting. (This definition applies to poplars).

### 1.62 Age

The age of plants may be expressed by indicating separately the time spent in the seedbed and in the transplant lines. Each transplanting is indicated by a "+" sign, and undercutting by the letter "u". Rooted cuttings may be prefixed "C" and stumped transplants (of poplars) by "S" e.g.:

| | | |
|---|---|---|
| 1 + 0 | 2 + 1 | C1 + 0 |
| 1 + 1 | 2 + 2 | C1 + S1 (poplars only) |
| 1 u 1 | 2 + 1 + 1 | |

Plants lined out during the growing season, as in summer lining-out, may be described as: $1\frac{1}{2} + \frac{1}{2}$; $1\frac{1}{2} + 1\frac{1}{2}$.

### 1.7 Common Market and Forest Nurseries

The effect of entry by Great Britain into the Common Market (European Economic Community) on British forest nurseries is unclear (early 1972). However, it is likely that attention will be paid to standards of plant quality and to seed origins, with the object of ensuring that seed and young plants moving in trade, and between member countries, are best fitted to the requirements of the planter.

FURTHER READING

BRITISH STANDARDS INSTITUTE, 1966. *Specification for nursery stock. Part 4. Forest Trees.* B.S. 3936: Part 4: 1966.

ALDHOUS, J. R., 1967. *Standards for sturdiness of forest tree plants.* Research and Development Paper No. 36, Forestry Commission, London.

ALDHOUS, J. R., 1967. *Review of research and development in forest nursery techniques in Great Britain, 1949–1966.* Research and Development Paper No. 40, Forestry Commission, London.

OLDENKAMP, 1971. *The quality of forest tree nursery stock* Nederlands, Bosbouw Tijdschrift 43(1), 1-7.

# Chapter 2
# SELECTION, LAYOUT AND FORMATION OF A NURSERY

Careful attention to the selection of a nursery site will amply repay all the effort involved. Failure to select a soil that is sufficiently acid inevitably results in costly and unsatisfactory production of many commonly planted species, while selection of sites which are unsatisfactory in other respects, e.g. on a heavy soil, weedy, or in frost-hollows, will sooner or later (and generally sooner) add to the cost of one or more operations or lead to unnecessarily high losses.

The physical limits within which sites should be sought are:

*Elevation:* In England and Wales, certainly not over 1000 ft/*300 m*, and preferably below 500 ft/*150 m*, above sea level. In Scotland, preferably below 300 ft/*100 m*. The higher the site, the colder it will be at all times of the year, the shorter the growing season and the greater the chance of the soil being frozen or covered with snow when plants are required or other work should be proceeding.

*Soil Depth:* There should be at least nine inches of soil; soils containing many large stones or much gravel should be avoided, especially if much machinery is to be used in the nursery.

*Rainfall:* This should not exceed 50 inches/*1250 mm*, nor should it be less than 30 inches/*750 mm*, unless irrigation can be laid on.

*Previous Land Use:* The previous use of the land may influence its value as a potential nursery site, because of the effect of some forms of husbandry on soil acidity and on the amount of weed present. Young plantations or any other type of woodland should not be spurned as possible sites for a nursery. The sites most readily converted to successful forest nursery production have been those covered with bracken or heather. Soils classified by texture as sands are not suited for production of poplars; for a poplar nursery, a sandy loam should be sought.

Nurseries are sometimes referred to according to the previous history of the site, being described as "heathland", "woodland" or "agricultural". These terms have never coincided exactly with any particular soil characteristic and the names are seldom used in any context of nursery planning or management.

At one time it was thought that heathland nurseries would quickly become exhausted and would need to be replaced after a few years. However, many heathland nurseries have remained productive after ten or fifteen years cropping. Those which have been abandoned have generally become fouled with weeds or have been limed excessively—faults attributable to bad management. At the same time, heavier fertilising is often required to sustain good growth in older heathland nurseries than in those up to five years old.

## 2.1 Site Selection

The factors to be taken into account within the physical limits given above when selecting a nursery site are:

Soil acidity (see Chapter 3, section 3.2).
Soil workability and drainage.
Freedom from weeds (see Chapter 10).
Local topography in relation to frost-hollows, exposure and aspect.
Access and services.
Labour supply.
Distance from markets.

Of these, the first three are the most important, but none can be safely ignored.

### 2.11 Soil Analysis

It is essential that a test of soil acidity be made on a sample of soil from any potential nursery site. (See Chapter 3, section 3.36 for instructions on taking soil samples). A chemical analysis may also be informative.

### 2.12 Soil Texture, Workability and Drainage

Forest nursery work should proceed in the winter and early spring, whenever the weather is mild. The ideal forest nursery soil should therefore be well-drained and free-working at this time of year and should contain only a little clay and fine silt. In the last twenty years, the majority of new forest nurseries have been established on sandy or loamy sand soils with a maximum of 10 per cent clay and 15 per cent silt; indeed, the soils in many such nurseries have practically no clay at all. Such nurseries have often been most successful and productive, and while these light soils usually retain relatively little water or soluble nutrients compared with heavy soils, they are usually acid and often weed free.

The higher the organic matter content of nursery soils, the better. A high organic matter content ensures good retention of nutrients and water and may improve the working properties of the soil. In most nurseries on sandy soils, there is at least three per cent of organic matter in the soil and in many Scottish nurseries of this type the figure may be up to ten per cent or more. On loamy soils, especially those which have been in cultivation for some time, the organic matter content is usually less than five per cent and in the east and south-east of England, it may be less than two per cent.

If drainage is not satisfactory, the possibilities should be investigated of subsoiling to break up any iron-pan or other compacted layer impeding drainage, or digging cut-off or other surface drains or ditches to prevent water entering the nursery and to lead away water accumulating within the nursery. In at least two large Forestry Commission nurseries, small hollows where water tended to accumulate have been filled with soil from adjacent higher ground and have been slightly domed so that water drains to the edges. Tile drains have also been laid in some nurseries, but if this is done, the tiles need to be put in at least 24 inches/*60 cm* deep, well below the depth of any subsoiler that may be used in the nursery.

## 2.13 Freedom from Weeds

Ideally, the site of a new nursery should be free from annual and perennial weeds and weed seeds. With proper management (i.e. continued vigilance and removal of weeds as soon as they are seen), such sites can be kept substantially weed-free for many years. The difference in the direct annual cost of weeding can be the difference between £120 and £20 per acre/*£300 and £50 per hectare*—quite sufficient to justify some effort in getting a weed-free site and managing it to remain substantially weed-free. As, however, this ideal is not often possible, means are described in Chapter 10 of eliminating most established perennial weeds, and of controlling annual weeds and newly germinated perennials by spraying, both in transplant lines and seedbeds.

## 2.14 Avoidance of Frost Hollows; Slope; Exposure

These three factors are all related to local topography. The most important is the avoidance of frost-hollows and hence the worst consequences of late spring frosts. Frost-hollows occur wherever cold air can accumulate—in the bottoms of valleys, large or small depressions, and where trees form a barrier to the drainage of cold air down a slope. Little can be done to reduce frost in natural frost hollows. But where trees form an artificial barrier, a gap at least as wide as the trees are high, created at the point in the barrier furthest down the slope, will enable the cold air to drain off.

Ideally, a nursery should lie on a gentle slope, with sufficient gradient to allow rain to run off without eroding the soil. Moderate slopes easily become eroded and are more difficult to work by machine, while flat ground may be subject to waterlogging and frosting. Sites which are exposed to strong winds from any direction, but particularly from the east, should be avoided unless protection by means of internal hedges etc. can be provided.

## 2.15 Aspect

There are various opinions about the best aspect for a nursery and only one point of agreement, namely that an easterly aspect should be avoided if possible, for the reason that the most damaging winds are the cold easterly winds of early spring and that if plants are caught by a late spring frost, the ill-effects are most acute if the plants are thawed rapidly by the morning sun.

Sites with a northern aspect should not be chosen if poplars are to be grown.

## 2.16 Access and Services

It is essential that vehicles can be driven into the nursery, so that plants and materials may be received and despatched, and tractors and implements brought in when required. The road should be metalled and be capable of taking a tractor or heavy lorry in all weathers.

A piped water supply is highly desirable, as much to provide washing and sanitation facilities for the staff as for the nursery itself. Similarly, electricity and telephone services are desirable but not essential.

## 2.17 Labour and Supervision

No nursery can be run without a labour force. The number of men or women required depends on the degree of mechanisation and the availability of alternative work which can keep the men employed at times when they are not wanted in the nursery. In practice, the labour requirement ranges from one man-year per acre/*0.4 hectares* to one man-year per four acres/*1.6 hectares*, the former being typical of small nurseries and the latter of a large highly mechanised nursery. There should be one ganger or senior worker for every ten to fifteen workers, while a forester or other supervisor will be required full time if the nursery exceeds thirty acres/*12 hectares*. The forester or nursery manager in charge of a nursery, whether full or part-time, should have had recent training or up-to-date experience in nursery work. Nursery management requires specialist knowledge and few untrained or inexperienced men do well in a nursery until they have gained that knowledge.

## 2.18 Access to Markets

Nurseries producing the bulk of their plants for sale are better sited near potential markets, though this consideration is less important than those already mentioned.

## 2.2 Layout of Nursery

### 2.21 Shape of Nursery

The nursery should be as compact i.e. as near square as possible, and regular in shape so as to minimise the length of boundary fence and to reduce the amount of time lost moving from one part of the nursery to another both by labour and supervisors.

### 2.22 Size and Shape of Sections

These should be related to the method of working, mechanisation, and need for hedges. (Section 2.25).

Sections should normally be not less than one acre/*0.4 hectares* in area, but if lining out is to be done by plough or lining-out machines, sections two or three acres/*1 hectare* in area are preferable so that machines can get a continuous run of between 100 and 150 yards/*metres* before they need to turn. If the nursery is exposed and hedges are required for local shelter, the hedges should be at right angles to the prevailing wind and should be planted along the longer side of the sections they need to shelter.

Some nurserymen arrange the size of sections so that in the direction of lining out, the number of plants filling a full line across the section is a multiple of 500; this eases control of piecework payments and lining out programmes.

### 2.23 Buildings*

Buildings should provide the following facilities:

(a) An office for the nursery manager and any clerks who may assist him. This must conform with the requirements of the Offices, Shops and Railway Premises Act, 1963.

(b) A store for machinery and tools—this may have an earth floor, though maintenance is easier if the floor is made of concrete. Any petrol or other fuel kept for machines must be stored in conformity with the Petroleum (Consolidation) Act 1928 and subsequent Regulations particularly the Petroleum Spirit (Motor Vehicles etc.) Regulations, 1929, 1948 and 1950, or any more recent amendments.

(c) A place for dry stores, preferably a room with a dry concrete floor. A part of this store should be lockable and used for storing pesticides. Fertilisers in paper bags should be kept in a dry store; those in polythene bags are better under cover, but if kept out of doors must have a waterproof sheet over them.

(d) A shed for plants awaiting despatch or just received. This store must be cool and adequately ventilated. See also Section 9.33, Storage of Plants in Polythene, and Section 9.35, Cold Storage of Plants.

(e) Separate mess room and washing and lavatory facilities for men and women staff. These should be up to the standards prescribed by the Agriculture (Safety, Health and Welfare Provisions) Act, 1956.

(f) An easily accessible cupboard or box for First Aid Equipment. (Agriculture (First Aid) Regulations, 1957—Statutory Instrument 1957 No. 940).

Some of the above can be combined in one building if convenient. On private estates, some of these facilities may be provided better in part of the estate office.

Nursery buildings should be located centrally in the nursery so that the distance both supervisory and working staff have to walk to a job is minimised.

While the main buildings need not be erected until a new nursery is well established, once work has started on forming a new nursery, a shelter and store for essential equipment should be available from the outset.

### 2.24 Roads, Paths and Alleys

The buildings should be served by an all-weather metalled road connecting it to the nearest public road. Permanent roads to nursery sections need only be sufficiently well surfaced to carry a tractor and trailer. Often the natural soil, when compacted by traffic, is adequate for this purpose but in nurseries on stony soil, stones from the sections should be thrown onto the most heavily used roads to reinforce them. Where possible a road should also be made round the perimeter of the nursery. This will ensure that machines can get in from both ends of all sections unless baulked by ditches or hedges, and will also provide a barrier against weeds encroaching from outside the nursery fence. Permanent roads should not be allowed to be covered with weeds. See Chapter 10 for means of keeping them clean.

Roads serving sections should always be at least 15 ft/*5 m* and preferably 18 ft/*6 m* wide so that tractors and implements can turn without damaging plants. On sloping ground, roads should cross the tops of sections so that loads carried inwards by hand or by barrow are taken downhill; corresponding exits are needed at the foot of each slope so that outward loads of plants need not be moved uphill by hand.

Paths within or between sections should always be considered temporary and should be cultivated

*Note. The Acts of Parliament, Regulations, etc., quoted here were in force in summer 1971. There is no guarantee that this list is comprehensive or that it will remain up-to-date.

whenever necessary. Paths should be at least three feet/*1 m* wide, that is, wide enough to wheel a barrow or small trolley.

Alleys between seedbeds or between beds or strips of transplants should normally be eighteen inches/*45 cm* wide. This will allow a tractor wheel to pass easily. However, if for any reason a tractor fitted with half-tracks has to travel over beds, the alley width should be increased to twenty-four inches/*60 cm*.

### 2.25 Hedges

In sheltered nurseries, hedges should be avoided. If the nursery or any part of it is exposed to strong winds, however, a hedge will provide valuable shelter to plants.

One disadvantage of hedges is that they impede the work of machines—since headlands are needed at both sides of a hedge unless the direction of work is parallel to it. Hedges can also harbour weeds, pests and diseases, they can root out into sections and compete for water and nutrients, they need to be cut regularly. If wrongly sited they can create frost-pockets.

If hedges are required, good quality plants should be put in at 18-inch/*50 cm* spacing along ground that has been trenched and treated with PK fertiliser, as for transplants, plus a liberal application of hop-waste or other weed-free bulky organic manure. The following species make good hedges: Lawson cypress, *Cotoneaster simonsii*, Western hemlock and holly. Tamarisk can be used in areas near the south coast. Unsuitable species include beech which may harbour aphis, Western red cedar which can become infected with 'Keithia' (*Didymascella thujina*), and Monterey cypress which may be killed in severe winters.

Hedges should be cut, not with vertical sides but tapering towards the top. In this way, branches at the base will remain alive and the hedge will not go thin at the bottom.

Roots of hedge plants may enter cropped areas and must be cut back every two or three years using a sub-soiler or by trenching.

## 2.3 Breaking-in a New Nursery

### 2.31 Sequence and Timing of Operations

Much the same sequence of operations is required whether the site is covered with trees, with heather and bracken or with grass, except that for grass and heather sites, the earlier operations are unnecessary. The best sequence is: removal of trees and scrub; removal of aerial parts of woody weeds; ploughing; cleaning (i.e. removal of woody roots); subsoiling; incorporation of initial application of nutrients; final cultivation.

If possible the nursery fence should not be erected until the cultivations are completed so as to give the greatest degree of freedom of manoeuvre to mechanical equipment for as long as possible.

Ideally, the felling of trees and removal of stumps and scrub should take place during the summer and be completed so that cleaning can go on in suitable weather until the beginning of the nursery season when the ground is to be cropped. Stones collected off the soil during initial cultivations, may be suitable for metalling the main nursery road.

### 2.32 Removal of Trees and Woody Weed Growth

On areas large enough to justify the economic use of mechanical equipment, a bulldozer fitted with a toothed grubber blade can be used to push out stumps and scrub. A toothed blade is preferable to a standard dozer blade; it does not disturb the soil more than is necessary and removes less soil with the roots, so making burning easier. If trees and tall scrub are present and a bulldozer is to be used, stems should be felled before bulldozing starts, leaving stumps between two and three feet high/*0.7 to 1 m*.

Alternatively, trees can be winched down with roots attached, either by tractor fitted with a winch or by hand winch. Within reason, the higher the winch cable can be attached up the tree to be removed, the easier the tree comes down.

All roots and lop and top from the cleared ground should be removed from the site. If such material is to be burned, the fires must be outside the nursery area otherwise the fungus *Rhizina inflata* may colonise the site and, in later years, kill young plants growing there.

In all the initial operations, as little subsoil should be brought to the surface as possible. Undesirable compaction of the soil can be minimised if every opportunity is taken to clear and prepare the site in dry conditions.

Low woody vegetation such as heather, bracken, bramble and gorse should be cut by auto-scythe, by "Swipe", or by rotary cutter, the loose vegetation raked up and taken off the site. Alternatively, if there is only a light cover of woody vegetation, it may be reduced to a mulch by a rotary chopper.

### 2.33 Initial Cultivation

On heathland and woodland sites, the surface mat of roots, grass and stumps of herbaceous weeds and heather must be broken up. The best means of doing this is to plough to a depth of between 4 and 6 inches/*10 to 15 cm*. Alternatively a giant rotovator can be used but this tends to break up woody roots too finely so that they are more difficult to collect up in subsequent cleaning operations.

Permanent grassland should be ploughed to a depth of eight inches and should not be rotovated, nor should the turf be removed from the site. This initial ploughing of grass should be done as early in the season as possible. Spraying with paraquat to kill the turf before ploughing may hasten its breakdown and reduce the unevenness of the first crop grown subsequently.

Any patches of couch or similar grass should be treated chemically about two weeks before ploughing. (See Section 10.61).

**2.34 Cleaning Cultivations**

The soils should next be worked repeatedly, alternately ploughing to about six inches/*15 cm* and harrowing or cultivating with spring tines until all the coarse woody remnants of stumps, stems and roots have been removed.

Once the initial cultivations have been completed, a careful watch should be kept for any patches of perennial weeds e.g. sorrel, couch, which may have survived. If these appear, appropriate steps must be taken to kill them before the first crops are sown or planted.

**2.35 Levelling and Grading**

During the cleaning cultivations, a skilful ploughman can move soil across a section to level out minor humps and hollows. Sections should slope evenly or, if on a flat site, should be slightly domed. Large-scale moving of top soil must be avoided, as the areas denuded of their top soil will produce poorer plants for several years afterwards.

**2.36 Subsoiling**

If there is any iron-pan or other hard layer of soil within 18 inches/*0.5 m* of the soil surface which may impede drainage or rooting, this may be broken up by subsoiling with a tine at intervals of four feet/*1.2 m* across the nursery. After running in one direction, a second series of runs should be made at right angles to the first. For best effect, the soil must be dry when subsoiling is carried out.

**2.37 Incorporation of Initial Application of Nutrients**

If a soil analysis indicates that the soil is too acid or is unduly low in phosphorus or magnesium, this can be adjusted by an initial application of lime (for excessively acid soils), ground mineral phosphate (for soils low in phosphorus) kieserite or calcined magnesite (for soils low in magnesium), basic slag (for excessively acid soils low in phosphorus) or dolomitic limestone (excessively acid soils low in magnesium). The amounts of each to be applied may be prescribed at the time of the analysis, or may be as indicated in Section 4.2. These additions may be made at any time in winter preceding the first crops, once the ground has been levelled.

**2.38 Final Cultivation**

The nursery site should finally be cultivated by ploughing to eight inches/*15 cm* or rotovating to a depth of six inches/*20 cm*. If any nutrients have been added, a rotovator incorporates these more thoroughly in the soil but it may be difficult to firm the soil sufficiently subsequently, if seedbeds are to be thrown up shortly after rotovation.

**2.39 Fencing**

Only one nursery in a hundred can safely be run without a rabbit fence, but only a small proportion need a deer fence. See *Forestry Fencing*, Forestry Commission Forest Record No. 80 (HMSO 35p), pages 46-48, for fence specifications.

## 2.4 Costs of Formation

Recent (1970) direct costs of establishing new nurseries have ranged between £50 and £200 per acre/*£125 to £500 per hectare* exclusive of overheads and the cost of the ground. This may seem a wide range but the higher costs have been associated with sites where a number of big boulders have been found which have not only been costly to move but have slowed the work. Even so, an initial outlay well over £200 is quickly recovered if the site is a good one and is properly managed.

# Chapter 3
# FOREST NURSERY SOILS

To ensure steady output from forest nurseries, first and foremost the soil must be sufficiently acid for the crop being raised and sufficiently light and well drained to be workable during the larger part of the winter. Freedom from weeds is an advantage, though less important than formerly because of the availability of herbicides. High nutrient reserves and high organic matter are useful but any consequences of deficiencies in these properties can largely be made good.

The fact that pre-existing nutrients in the soil are only of secondary importance reflects a revolution in husbandry. Before 1940, plants in forest nurseries largely depended for their nutrients on what was stored in the soil. Farmyard manure or lime might have been applied but this was as much to benefit a greencrop as forest trees. Only the soils with better reserves—the traditionally more fertile soils—could sustain any worthwhile crops. Now it is generally accepted that each crop must be given a plentiful supply of mineral nutrients if vigorous stock is to be raised; plentiful reserves of nutrients in the soil are beneficial but the level of the pre-existing reserves is no longer the main factor that determines productivity.

## 3.1 Physical Characteristics

The soil is composed mainly of particles derived from the parent rocks together with humus and partly decayed residues of dead plants and soil animals. The texture (Section 3.11) of the soil is determined by the proportions of different sizes of mineral particle; the structure (Section 3.13) of a soil is determined by the extent to which the particles adhere together to form natural aggregates.

The growth of crops and their response to fertilisers can be very much affected by the physical condition of the soil. If drainage becomes impeded, for example if a plough pan or compacted layer is formed by cultivating when the soil is too wet, poor aeration and slow drainage in the soil may give rise to poor plant growth and yield, in spite of the most carefully conceived fertility regime.

### 3.11 Texture

Soil texture is defined by the proportion of particles of different size in the soil. Several classifications exist, the 1951 USDA system being used here (United States Dept. of Agriculture Handbook No. 18, 1951). Sand (particles from 2 to .05 mm in diameter) and silt (particles from .05 to .002 mm) mainly consist of minerals derived from parent rock unchanged by weathering; in contrast, the clay fraction (<.002 mm) consists predominantly of colloidal minerals formed as products of weathering and not found in unweathered rocks. The origin or composition of the particles does not affect the definition of texture. Thus the sand particles may be 90 to 95 per cent quartz—e.g. in soils derived from sedimentary deposits; alternatively the sand particles may include substantial proportions of felspar or mica, for example if derived from granitic rocks, or they may be composed of calcium carbonate as in seashore dune sands where particles of broken seashells abound.

Clay particles in the soil have two important properties: the ability to hold or combine with nutrients required by plants, and the property of swelling and shrinking as the soil becomes wetter or drier. This latter property has a major influence on the structure of the soil and the ability of the soil to form aggregates, such as the "crumbs" composing the surface of seedbeds at sowing time on loamy or heavy soils.

Natural drainage channels in clay soils occur only between aggregates of particles and are open only when some shrinkage has taken place in the clay. The spaces between individual clay particles are minute and when filled with water do not drain under the force of gravity.

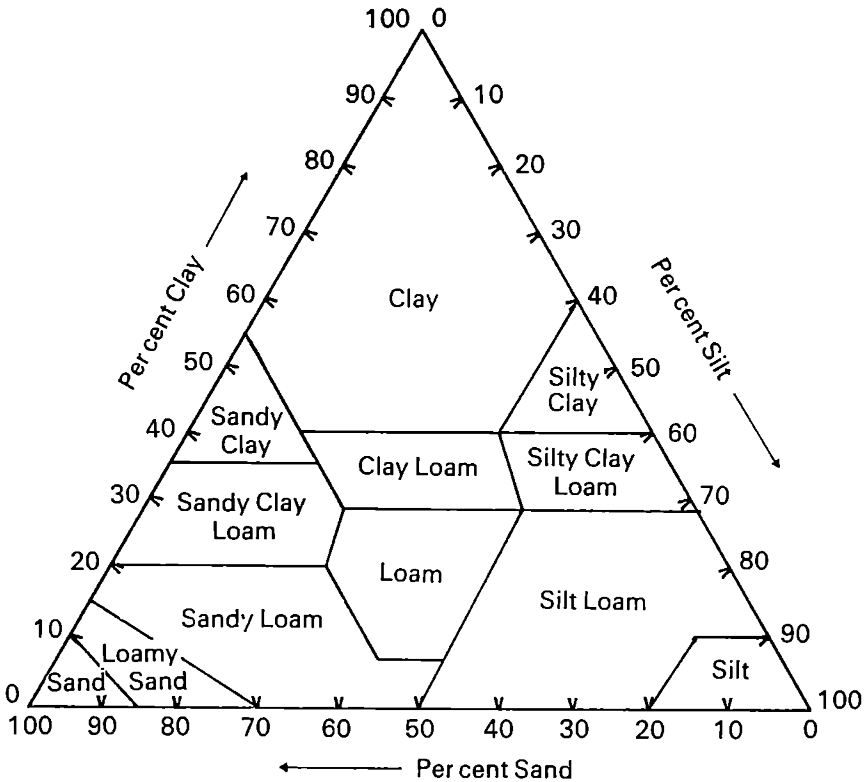
*Classification by Texture*

The proportions of sand, clay and silt present in each soil can be the basis of an objective soil classification. Several alternative classifications have been made; one of the best known which is widely used is shown in Fig. 1.

*Texture of Forest Nursery Soils*

An ideal nursery soil should be well drained, stonefree, and have a maximum of 10 per cent clay and 15 per cent of silt. Soils within these limits fall into the texture classes; sands, loamy sands and sandy loams. Good nursery crops can also be grown on soils with less than 10 per cent silt and clay—by definition sands, though more attention has to be paid to the supply of nutrients on such soils.

Some soil characteristics such as pH and nutrient status can be modified fairly readily within certain limits by the nurseryman. Soil texture, however, can only be modified at a greater expense than is generally acceptable. Only if the soil is of the right texture is it possible to produce successful annual crops of tree seedlings and transplants regularly.




The composition of the textural classes of soils, the sizes of particles being:—
sand 2–0·05 mm, silt 0·05–0·002 mm, clay below 0·002 mm.
(Based on the system set out in the United States Dept. of Agriculture Handbook No. 18, published 1951)

Fig. 1. Soil texture classification.

On the heavier soils, winter work may become impossible in wet periods and frost-lift may also be a serious problem, limiting autumn lining out. In addition, within the range of soils commonly encountered in forest nurseries, the heavier the texture, the easier it is to create a cultivation pan (Section 3.15).

### 3.12 Organic Matter and Humus

Organic matter is not taken into account in the standard soil texture classifications. Nevertheless humus in the soil holds moisture and nutrients as clay does, but without its stickiness. Soils low in clay but relatively high in organic matter are probably ideal from the point of view of texture for forest nurseries.

Organic matter in soil varies considerably. One important practical distinction however is between raw organic matter and humus. Raw organic matter consists mostly of remains of plants, usually partially decomposed, but still retaining part of the original plant structure. During decomposition, the proportion of cellulose and hemicellulose in plant tissues is usually reduced in relation to the lignin constituent. This lignin breaks down much more slowly and its colloidal, dark-coloured residues form the bulk of what is called humus. Any chemical determination of organic matter may include raw organic matter besides humus proper, as well as the live tissues of soil bacteria and fungi, though these last two sources form a relatively small part of the organic matter so determined. However, colloids derived from bacteria may form an important constituent of humus.

Humus swells or shrinks in response to wet or dry conditions respectively and thereby assists in establishing and maintaining good soil structure. Raw organic matter can also have an important effect on soil structure, partly by its own physical presence as a discontinuity in the soil mineral matter and partly as a site of bacterial and fungal activity where organic colloids are present in far greater concentrations than normal.

When a new nursery is established on land previously under semi-permanent heathland, woodland or perennial grass vegetation, the organic matter content of the soil diminishes until in equilibrium with the new soil condition associated with annual cropping. The breakdown of the initial "surplus" of organic matter may be quite rapid, especially if the soil pH is raised by liming. The improved aeration resulting from cultivation is an important factor stimulating this biological decomposition of organic matter. As breakdown proceeds, plant nutrients are released, thus giving rise to the outstanding growth of plants in the first years of many heathland nurseries.

### 3.13 Structure

In contrast to texture, structure describes the way the soil particles are aggregated. Soils have their individual particles clustered together into crumbs, clods, blocks, etc., though in sandy soils these are weakly developed and easily break up. The shape and size of these aggregates principally determine the structure. How densely aggregates are packed together also is part of the description of the structure of any soil.

One, if not the most important effect of a good soil structure is to ensure good drainage and aeration, the gaps between individual aggregates being the main channels for the movement of excess water. Loss of structure implies that soil becomes denser, the large pores disappear and drainage is impeded. See also Section 3.15.

### 3.14 Air and Water, Pore Space and Compaction

Soil may be described as a mass of particles, more or less aggregated together and permeated with a network of channels or pores. Some fundamental soil properties derive from the geometry of this pore space, for example, the amount of air or water present, the rate at which air diffuses and the rate at which water percolates down through the soil.

In a soil with a good structure, between 40 and 60 per cent of the volume should be occupied by pores. If the pores are reduced to 10 per cent of the soil volume or less, plant growth becomes impossible.

Pore size has a most important effect on the tenacity with which water is held in the soil. In pores with a diameter of less than about 0.03 mm, the water is held with a force greater than that of gravity, while in pores larger than this the water can drain away. Thus clay soils with a high proportion of very small pores, hold much water while sandy soils have few small pores and retain little. Plants extract "available water" from the soil until they can get no more, when they reach "wilting point".

Only about 0.5 inch/*12.5 mm* of water* is "available" in the top 6 inches/*15 cm* of coarse sands; on heavy clays, up to 1.0 inch/*25 mm* of stored water is available, while on loamy soils with a high proportion of fine sand, 1.0 to 1.25 inches/*25 to 30 mm* of water is available. In practice, obviously, plants on very coarse-textured soils, with a small reserve of available water are more likely to suffer from drought than plants on medium-textured soils.

The pore-size distribution in soil is determined partly by the texture and partly by the structure, which in the upper layers of cultivated soils can be markedly affected by management. In a loamy soil, a crumb structure, whether produced by skilful cultivation or by substantial additions of organic matter, will not only increase the amount of pore space but also the proportion of large pores, so improving the natural drainage and surface aeration.

Heavy dressings of organic matter can have a marked effect on the moisture-holding capacity of light soils, and increases of up to 70 per cent have been reported in agricultural practice. A similar effect has been observed in the woodland nursery at Teindland in Moray, where regular dressings of hopwaste have maintained the original exceptionally high organic matter content and the water-holding capacity of the soil, while without hopwaste both have fallen markedly; the stability of the very small soil crumbs has also been improved. (Table 13, page 29).

### 3.15 Plough Pans and Soil Capping

A plough pan is essentially a compacted layer where soil aggregates are more densely packed and some may have lost their structure by being rubbed and pressed together.

Once present, the pan may interfere with free drainage and thus cause temporary waterlogging leading to root death, or it may interfere with root penetration.

A pan will usually develop whenever soil is frequently cultivated to the same depth, whether by repeated passes of the plough share and tractor wheel or by rotovating or by use of a tine cultivator; pans are most readily formed when any of these operations are undertaken when the soil is wet.

There is a strong risk of plough pan formation when ground is repeatedly cultivated during fallow periods to control weeds. This risk can be minimised by ensuring that mid-season cultivations are to a depth of at least 2 inches/*5 cm* less than the final autumn ploughing which should be to full cultivation depth. Any plough pan formed during the summer should be broken up before the winter by use of a subsoiling tine at 2½ to 4 ft/*0.9 to 1.3 m* intervals and

**Note.* i.e. water equivalent to ½ inch/*12.5 mm* of rain.

working first in one direction then at right angles to it. The soil should be dry at the time of subsoiling.

Plough pans can easily form and any slowness in disappearance of water following heavy rain or any unexpectedly poor health of stock, especially transplants, should immediately lead to a test to determine whether a plough pan is present. Lodgepole pine transplants of inland origins seem particularly sensitive to temporary waterlogging of this sort.

A pan may be detected by digging carefully into the suspect area. The spade should be handled very gently and only a shallow layer of soil removed at a time. A pan will be apparent by the occurrence of compact soil at a depth of between 4 and 8 inches/*10 and 20 cm* according to the depth of cultivation. Once the pan is passed through, the soil may become less compact again. An alternative method of detection is to dig a pit to a depth of 10 to 12 inches/*25 to 30 cm*, carefully expose a clean face on one wall and with a pencil point probe the soil at ½ to 1 inch/*1 to 2 cm* intervals down the profile. Any compact layer can be detected by greater resistance to the probe. A cruder alternative is to probe vertically with a sharp strong rod.

Visually, compacted layers sometimes appear to be lighter or greyer in colour than the soil either side.

All these methods require a sensitive touch, but this can be acquired with a little practice. Any forester who has to work in forest nurseries should acquire the skill to test for plough pans at the earliest opportunity.

Capping of the soil, i.e. the formation of a thin, smooth, almost impermeable crust, is common after heavy rain, and may be particularly common on sandy loams and on silty soils low in organic matter. Water may run off a capped soil more rapidly in heavy storms than if the soil surface is loose, thereby rendering the rainfall less effective in replenishing soil-moisture reserves. Such rapid run-off also occasionally leads to soil erosion. Otherwise, there is no evidence that soil capping is harmful in forest nurseries. Surface cultivation can break up the cap, but when a vigorous crop of seedlings or transplants is growing, the cap is unlikely to be damaging. Capping is less prevalent where the organic matter content of soil is high and it is unlikely to be serious in seedbeds where a suitable grit cover is used, or on fallow ground which is cultivated regularly.

## 3.2 Soil pH

Soil acidity or soil reaction is commonly referred to in terms of the pH scale where a value in the range 6.5 to 7.5, measured in water, indicates a neutral soil, values from 5.5 to 6.5 indicate slightly acid soil, from 4.5 to 5.5 acid soil, and less than 4.5 very acid soil. Soil pH values of 3.5 or less are rare. Soil pH values above 7.5 indicate alkaline soils.

In the laboratories of the Forestry Commission, the Agricultural Development Advisory Service and the Macaulay Institute for Soil Research, the pH of soil is measured electrically after the soil has been mixed with water. Some workers at Rothamsted Experimental Station and elsewhere use solutions of calcium chloride. Measurements made in calcium chloride solution are usually about 0.5 less than those made in water. This difference has to be remembered when examining the pH response curves given in Forestry Commission Bulletin No. 37 *Nutrition Problems in Forest Nurseries* (diagrams 7-13, pages 36-44).

The pH, as determined in the field or laboratory, varies a little not only with method of measurement but also with time of year and crop. It will tend to be higher in cool, moist weather and in winter than in hot dry weather and in summer; it will also be higher in summer under a crop than under bare fallow. Thus differences in soil pH of less than 0.2 should be ignored. Where possible comparisons should be based on samples taken at the same time of year and following a similar crop. For production nurseries, sampling in the autumn on fallow land is ideal.

### 3.21 Plant Growth and pH

Most seedling conifers grow best in soil with a pH between 4.5 and 5.0. Spruces, hemlock, Lodgepole pine and larch grow more slowly in soils with a pH much outside this range and, under otherwise identical conditions, may be less than half as tall on neutral soils (pH 6.5-7) as on acid soils. Scots pine, Corsican pine, Norway spruce and Douglas fir are less intolerant of slightly acid or near-neutral soils, though these species still do best in acid conditions. Western red cedar on the other hand grows better on slightly acid soil (pH 5.5-6.5) than on acid soil, but this is the only commonly planted conifer for which this has been established.

There has been little research into the pH responses of hardwoods. However, practical experience and limited research show that most hardwoods, e.g. oak, alder, beech, birch and sycamore grow well on acid soils, but that there are some important exceptions, namely poplars and ash which require slightly acid or neutral soil and will not tolerate acid soils.

For most crops, an acid soil is therefore either essential or at least satisfactory. If both conifers and poplars are to be grown, an acid soil should nevertheless be sought as it is easy to make an acid soil less acid by adding limestone or chalk but more difficult to acidify a neutral soil. Some nurserymen have limed a section of an otherwise acid nursery and keep this section solely for the production of hardwoods.

### 3.22 Changes in pH

The pH of soils is most readily changed by liming which raises the pH and makes the soil less acid (see the following section). Liming is usually a deliberate and controlled attempt to influence soil acidity, but the pH of soils can also be altered by certain fertilisers sometimes used in forest nurseries, some fertilisers acidifying soil more rapidly than others. (See Section 4.4 *et seq* for details).

The rate at which soil pH may change depends on their texture. The resistance to change, the "buffer capacity", is largely proportional to the organic matter and clay content of the soil (and in neutral and alkaline soils, the carbonate content, but this last is not relevant to forest nursery soils). A strongly buffered soil is likely to provide a more constant environment for plants than a soil that is weakly buffered; light sandy soils are however usually in the latter category, unless very well provided with humus.

### 3.23 Making Soils Less Acid

Where the soil is too acid, it can readily be brought to the optimum for the crop by adding lime in one of its several forms. For forest nurseries, however, several warnings must be given. Firstly, many light sandy soils are weakly buffered, therefore, the pH of such soils may be very readily raised by liming; secondly there is only a moderate range of pH over which optimum growth is obtained. To these must be added the fact that most weeds are less vigorous on very acid soils. Thus it is of the greatest importance:

(a) to apply lime evenly,

(b) not to apply excessive doses,

(c) to keep if anything on the acid side of the optimum.

The amount of lime required depends on a combination of the buffer capacity of the soil—this is most readily related to texture—and the extent to which the pH has to be raised. A guide which can be used in the absence of any other information is given in Table 3, page 16. Soils are grouped in four texture classes.

Within each soil texture class, three columns are given. Use the values in the first column (to raise the pH to 5.0) whenever the sections to be treated are likely to be used for conifer production. Values in column two (to raise the pH to 5.5) may be used if the sections to be so treated are for hardwoods only, while the values in column three should only be used for sections devoted to the raising of poplar or ash.

Soils laboratories are also able to determine the "lime requirement" of soil (i.e. the amount of lime required to raise the pH to a given value) from samples sent in for analysis. If the lime requirement is to be determined, the laboratory must be told the desired optimum pH for the soils being analysed; the recommendations resulting from the analysis must be checked against the values shown in Table 3 for the pH and soil textures of the samples. If the "lime requirement" exceeds the value derived from the table by more than 5 cwt per acre/*625 kg per hectare* the divergence should be discussed with the soil chemist doing the analysis. If in doubt, always adopt the lower value of the two.

*Liming Materials* (See also Sections 4.22 and 4.44)
The forms of chalk and limestone from the various geological deposits are, when finely ground, of equal value as means of raising the pH of soils even though there may be small differences in the amount of other materials present.

Dolomitic limestone provides Mg in addition to lime and can be used where, in addition to raising the pH, the Mg reserves in the soil have also to be increased.

Dolomitic limestone may be taken as equivalent weight for weight to ordinary ground limestone or chalk, and at the same time, equivalent weight for weight, to Epsom salts as regards supplying magnesium.

Magnesian limestone contains less Mg than dolomitic limestone but may be considered as its equivalent for all practical purposes.

Basic slag has been recommended in the past; it contains some free lime as well as phosphate and is equivalent to about two thirds its weight of ground limestone, but see section 4.22, page 24.

In the past, the pH of many nursery soils was raised unwittingly, when grits containing lime were used as seedbed covers and when basic slag or composts made with liming materials were applied to greencrops and trees. In recent years, foresters have understood such dangers and have used lime-free grits etc. Periodic checks must be carried out however to ensure that in particular, the grits currently in use for covering seed are lime-free.

If in doubt about the suitability of a grit, take a sample (about a tablespoonful), put it on a clean saucer or shallow bowl and pour over it a little dilute hydrochloric acid. If the grit fizzes or individual particles of the grit fizz, limestone is present and the grit is unsuitable.

Hard water has also raised the pH of sections which have been heavily irrigated for several years.

TABLE 3

HUNDREDWEIGHT PER ACRE OF MAGNESIAN LIMESTONE, GROUND LIMESTONE OR GROUND CHALK TO RAISE THE pH OF SOIL TO APPROXIMATELY 5.0 (FOR NORMAL FOREST NURSERY PRODUCTION); 5.5 (FOR SECTIONS DEVOTED TO HARDWOODS); OR 6.0 (FOR SECTIONS TO POPLARS)

| pH by soil analysis | Soil Texture Class: 1 Sands, loamy sands | | | 2 Sandy loams | | | 3 Silty loams, silt loams, loams, sandy clay loams | | | 4 Clay loams, silty clay loams, clay | | | 5 (Soils in class 4, but high in organic matter) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cwt lime per acre to raise soil pH | | | | | | | | | | | | | | |
| | 5.0 | up to 5.5 | 6.0 | 5.0 | up to 5.5 | 6.0 | 5.0 | up to 5.5 | 6.0 | 5.0 | up to 5.5 | 6.0 | 5.0 | up to 5.5 | 6.0 |
| 3.0 | 40 | 50 | 60 | 48 | 61 | 72 | 65 | 81 | 97 | 80 | 100 | 120 | 95 | 119 | 143 |
| 3.2 | 36 | 46 | 56 | 44 | 56 | 68 | 58 | 75 | 91 | 72 | 92 | 112 | 86 | 109 | 133 |
| 3.4 | 32 | 42 | 52 | 39 | 51 | 63 | 52 | 68 | 84 | 64 | 84 | 104 | 76 | 100 | 124 |
| 3.6 | 28 | 38 | 48 | 34 | 46 | 58 | 45 | 62 | 78 | 56 | 76 | 96 | 67 | 90 | 114 |
| 3.8 | 24 | 34 | 44 | 29 | 41 | 53 | 39 | 55 | 71 | 48 | 68 | 88 | 57 | 81 | 105 |
| 4.0 | 20 | 30 | 40 | 24 | 36 | 48 | 33 | 49 | 65 | 40 | 60 | 80 | 48 | 71 | 95 |
| 4.2 | 16 | 26 | 36 | 20 | 32 | 44 | 26 | 42 | 58 | 32 | 52 | 72 | 38 | 62 | 86 |
| 4.4 | 12 | 22 | 32 | 15 | 27 | 39 | 20 | 36 | 52 | 24 | 44 | 64 | 29 | 52 | 76 |
| 4.6 | 8 | 18 | 28 | 10 | 22 | 34 | 13 | 29 | 45 | 16 | 36 | 56 | 19 | 43 | 67 |
| 4.8 | 4 | 14 | 24 | 5 | 17 | 29 | 7 | 23 | 39 | 8 | 28 | 48 | 10 | 33 | 57 |
| 5.0 | | 10 | 20 | | 12 | 24 | | 16 | 33 | | 20 | 40 | | 24 | 48 |
| 5.2 | | 6 | 16 | | 8 | 20 | | 10 | 26 | | 12 | 32 | | 14 | 38 |
| 5.4 | | 2 | 12 | | 3 | 15 | | 3 | 20 | | 4 | 24 | | 5 | 29 |
| 5.6 | | | 8 | | | 10 | | | 13 | | | 16 | | | 19 |
| 5.8 | | | 4 | | | 5 | | | 7 | | | 8 | | | 10 |

*Notes.* (1) If the soil contains more than 10% organic matter, use the next higher soil texture class; e.g. if the soil is a loamy sand, the values in the first set of three columns would normally be appropriate. However, if the soil organic matter of such a soil exceeds 10%, use the set of columns headed "Sandy loams".

(2) To convert to kg per hectare, multiply figures in table by 125.

(3) To convert to tonnes per hectare, divide figures in table by 8 or multiply by 0.125.

(4) 1 hundredweight (cwt) = 112 lbs.

### 3.24 Acidification of Soils

While it is easy to neutralise an acid soil, it is more costly to acidify a soil when the pH is too high. Where a substantial amount of free lime is present, acidification is practically impossible. Every forester should, therefore, avoid measures which make the soil less acid than he requires it, and, of course, a soil with a naturally high pH should never be chosen for a nursery.

Soil without free lime may be acidified over a period of several years by regular use of ammonium sulphate applied as top-dressings to crops. The ammonium-nitrogen in this fertiliser is either taken up directly by the plant, or on soils with a pH over 5.5 is converted to nitrate in the soil, leaving the free sulphate which is the principal acidifying agent. The nitrate-nitrogen also acidifies as long as it is not taken up by plants.

More rapid acidification can be achieved by a single heavy winter dressing of sulphate of ammonia. A dressing of 30 cwt per acre/*3750 kg per hectare* has reduced the pH by between 0.75 and 1 unit (Benzian, 1965). However, such heavy winter dressings may result in excessively high concentrations of soluble salts and no risk of scorch to plants, during the subsequent growing season.

Alternatively, soils can be acidified by additions of screened rock sulphur, or with flowers of sulphur. Rock sulphur has been used successfully in several Scottish forest nurseries. However, the risk of damage in a dry spring is greater with sulphur than with ammonium sulphate. In either case, the sulphur is oxidised in the soil and forms sulphuric acid. Sulphuric acid has also been applied direct to soils experimentally. Ferrous sulphate is used in horticulture for acidification but not, so far as is known, in British forest nurseries.

The quantity of sulphur required for acidification depends on the pH of the soil and the pH required. In experiments in England, 10 cwt of sulphur per acre/*1250 kg per hectare* were required to procure a drop of between 0.75 and 1.0 pH unit, while in Scotland 4 or 5 cwt/*500 or 625 kg* have had the same effect. In some nurseries, the soil once acidified has stayed acid while in others the pH has slowly drifted back towards its original value.

### 3.25 Maintaining the Status Quo; and the Effect of Nitrogen Fertiliser on pH

"Nitro-chalk" was originally made with the intention of supplying nitrogen to nursery crops without materially affecting the pH. Experiments in which "Nitro-chalk" containing 15.5 per cent N has been used as a top-dressing to seedbeds without materially altering the pH, show that the fertiliser achieved its intended effect.

In recent years, however, the content of nitrogen in this and similar proprietary fertilisers, e.g. "Nitrashell", has been increased and the ratio of acidifying to neutralising constituents changed. Light forest nursery soils treated with "Nitrashell" and the new form of "Nitro-chalk" are likely to become more acid, though only slowly.

The effects on soil pH of fertilisers like ammonium nitrate and the relatively new materials such as iso-butylidene diurea and magnesium ammonium phosphate are less certain. The first is more likely to acidify strongly while the last may make soils less acid.

The acidifying effect of ammonium sulphate is described in the previous section.

## 3.3 Soil Analysis

Many attributes of the soil can be the subject of chemical or physical analyses. However, only those which can be influenced by management are discussed below. Permanent attributes such as texture (Section 3.11) while of critical importance in selecting sites, are of small significance in relation to day-to-day control of fertility.

While chemists have been examining agricultural soils for many years, forest nursery soils have received much less attention. Cooke (1967) discusses fully the values and the limitations of soil analysis and emphasises the risks of extrapolating results from one crop to another, or from one soil series to others derived from unrelated parent material.

Soils are normally analysed for P, K, Mg, pH and lime requirement. Some laboratories also determine the percentage of organic matter. The analytical methods, especially in England and Wales, have been based on agricultural crops and agricultural soils; for forest nurseries it seems at present best to treat the results of soil analyses as indicators of any need to boost reserves in the soil *in addition* to supplying, through fertilisers, the current needs of the crop.

In paragraphs 3.31 *et seq*, tables are given showing the range of values likely to be obtained when analysing soil for P, K and Mg. The two sets of values and indices given are those currently in use by the laboratories most likely to analyse forest nursery soils, i.e. the A.D.A.S. Regional Soil Laboratories in England and Wales, and the Macaulay Institute in Scotland.

The Agricultural Development Advisory Service (A.D.A.S.) analysis categories do not correspond to those used by the Macaulay Institute for Soil Research at Aberdeen, but as can be seen below, they can be related for practical purposes. Note also that A.D.A.S. results are in terms of element (P : K : Mg) while Macaulay Institute results are in terms of oxide ($P_2O_5$ : $K_2O$ : MgO).

The recommendations in paragraphs 3.31-3.33 are probably reasonable for sandy loams and loamy sands of moderate organic matter content (say, between 2.5 and 7 per cent). For heavy soils, or soils with a much higher organic matter content, they will be less reliable.

It has usually been considered that balance, i.e. a similar analysis index for P, K and Mg, is as important as the actual values, and if P and K, or K and Mg are badly out of balance, then deficiency symptoms are more likely to appear in plants.

### 3.31 Phosphorus

Results of soil analysis for P indicate whether it is necessary to boost the reserve of P by means of an extra application at the first opportunity after analysis.

### 3.32 Potassium

Forest nursery soils which are light and acid usually contain little K and may have a limited capacity to store any reserves. Additional fertilisers containing potassium should therefore be added as a matter of routine as top-dressings for each crop on such soils. Soils containing more adequate levels of K will need less top-dressing with K or possibly none at all.

### 3.33 Magnesium

The presence or absence of deficiency symptoms and results of soil analysis should determine whether to apply magnesium for each crop until the next analysis, or alternatively whether to apply magnesian limestone both to raise pH and increase reserves of Mg.

TABLE 4
PHOSPHORUS CONTENT OF SOILS BY ANALYSIS

| A.D.A.S. Analysis | | Action Recommended in Addition to Standard Treatment** | Macaulay Analysis | |
|---|---|---|---|---|
| Analysis results Parts per million P | Index | | Analysis results milligrams/100 g $P_2O_5$ | Index |
| 0–2.0 | 0 | Apply 10, 7, 5 cwt of ground mineral phosphate per acre 1,250, 875, 625 Kg per ha respectively | <1.6 | VL (very low) |
| | | | 1.6–5 | L (low) |
| 2.1–5.0 | 1 | | 5.1–8 | SL (slightly low) |
| | | | 8.1–11 | S–SL* |
| 5.1–10.0 | 2 | | 11.1–25 | S |
| 11–20 | 3 | | >25 | SH/H† |
| 21–40 | 4 | | | |
| (A.D.A.S. scale goes up to 9 but the higher indices are relevant mainly to glasshouse soils) | | | | |

*S = Satisfactory.
†Slightly High to High
**Standard treatment is to add for each crop 50–100 lb P per acre (20–25 for green-crop)/60–120 kg P per ha (25–30 for green-crop); see Table 8.

TABLE 5
POTASSIUM CONTENT OF SOILS BY ANALYSIS

| A.D.A.S. Analysis | | Action Recommended in Addition to Standard Treatment* | Macaulay Analysis | |
|---|---|---|---|---|
| Analysis results Parts per million K | Index | | Analysis results milligrams/100 g $K_2O$ | Index |
| 0–50 | 0 | Top dressing with K essential especially on light soils. See table 8. | <1.6 | VL |
| | | | 1.6–5 | L |
| 51–100 | 1 | Perhaps top-dress with K | 5.1–8 | SL |
| | | | 8.1–11 | S-SL |
| 101–200 | 2 | | 11–25 | S |
| 205–350 | 3 | No top-dressings necessary | >25 | SH/H |
| 350–500 | 4 | | | |
| (Index scale goes up to 9). | | | | |

*Standard treatment is to apply 100–150lb K per acre in spring to each crop/ 125–185 kg per ha; see table 8.

TABLE 6
MAGNESIUM CONTENT OF SOILS BY ANALYSIS

| A.D.A.S. Analysis | | Action Recommended in Addition to Standard Treatment* | Macaulay Analysis | |
|---|---|---|---|---|
| Analysis results Parts per million Mg | Index | | Analysis results milligrams/100 g MgO | Index |
| 0–25 | 0 | Apply 50 lb magnesium per acre/60 kg per ha to each crop. Use magnesian limestone whenever pH has to be raised. See Table 9. | 2 | L |
| 26–50 | 1 | | 2–4 | SL |
| 51–100 | 2 | Annual magnesium applications probably not necessary. Use magnesian limestone whenever pH has to be raised. See Table 9 | 4–6 | S–SL |
| 101–177 | 3 | | 6 | S |
| 178–252 | 4 | | | |

*Magnesium is not normally applied unless shown to be necessary by foliage discoloration or by soil analysis.

### 3.34 Interpretation of Results of Soil Analyses

While a soil analysis is a highly informative guide to managers, it is most important to realise that it is not an exclusive basis for recommendations for any fertiliser regime. The nursery forester has other sources of information which may support or modify recommendations based on soil analyses. The most important of the other sources is the knowledge of his plants' performance over the last two or three years in relation to the fertiliser used. This and the knowledge of what can be achieved in productive nurseries should give him a good idea of the extent by which his current practice needs to be modified to achieve such aims as high out-turns of usable one-year seedlings and one-year transplants. He should also know whether his plants show deficiency symptoms at any time during the year. The forester should have some idea of how his soil handles, and its texture, structure and capacity to retain nutrients; he should, as well, be aware of features of local climate which affect responses to fertilisers, e.g. high summer rainfall or regular spring drought.

Where in doubt, and where information is not otherwise available, properly designed and laid-out fertiliser trials can provide information leading to more confident prescriptions for fertility maintenance.

### 3.35 Recommendations to Apply Lime

One particular aspect of soil analysis that should always be looked at critically and checked against table 3 and section 3.23 is any recommendation to apply lime. Many soil laboratories are accustomed to handling agricultural soils and to applying agricultural standards of lime requirement, and an error could easily occur here. If any lime recommendation seems excessive, ask for confirmation of the figure recommended, making it quite clear what is the desired optimum pH for the nursery soil.

### 3.36 Sampling of Soil for Analysis

Before any samples of soil are taken, contact should be made with the laboratory doing the analysis. Agreement must be reached about when and how many samples are required and the sampling and labelling procedure to be followed. Laboratories which may analyse forest nursery soils are listed in Appendix III. The method of sampling likely to be recommended is given in section 3.37.

Samples should be taken in the autumn unless otherwise agreed, so that variations according to the time of year are minimised. It is preferable that soils should be sampled regularly every three or four years.

Analysis may take some time; allow for at least six weeks between sending samples and getting the results. Each section is best sampled before green-cropping or during bare fallow, whichever is normally part of the rotation. Samples should be taken in dry weather, but if this is impossible, the soil laboratory should be consulted before any drying of soil is attempted. In England and Wales, soils are preferred undried.

Any covering letter and accompanying label on the soil sample should, between them, give the following details:

Name and address of sender (to whom results will be returned).
Location of nursery if different from above.
Number of samples sent.
Analyses required.
Optimum pH desired for each section.
Date and reference of previous soil analyses.
Crops and fertilisers since the last analysis.
Any relevant information, e.g. deficiencies observed, high summer rainfall.

**3.37 Method of Soil Sampling**

First decide what areas should be sampled. Normally, each nursery section should be sampled separately unless two or more sections are of the same parent material, have similar drainage conditions and have been treated identically for several years.

Any sub-section or part of a section which visibly differs from the rest of the section, or on which plants regularly grow markedly better or worse than elsewhere in the section, should be sampled separately.

It is important to determine the normal depth of cultivation, especially in heathland nurseries.

For each section to be sampled, the aim is to get as representative a soil sample as possible. This can be done by collecting about 24 small equal samples from points evenly distributed over each sample area. Small sections may be less intensively sampled, but a minimum of 10 samples should always be taken. Sections may be traversed following a W pattern, and taking six samples from each leg of the W; other sampling patterns may be used if preferred.

Samples may be taken with an auger or a spade. An auger is preferable and if samples are to be taken regularly, a suitable tool should be obtained for this purpose. Sampling by spade necessitates additional work mixing samples and sub-dividing to reduce the bulky sample to the amount required for analysis.

*Sampling by Auger*

There are special soil augers of $1\frac{1}{4}$ inch diameter/*approx. 3 cm* for taking samples; wood augers of similar size can also be used if the shank is lengthened. Screw the auger into the soil to the full depth of normal cultivation, pull it out with the soil sticking to it, then take the soil off and put it in a clean bucket. Continue this procedure, as outlined in the preceding paragraph, until the whole section has been covered and sufficient soil collected (i.e. about 2 lb/*1 kg*). The soil should then be well mixed and put in a polythene or cotton bag.

*Sampling by Spade*

If using a spade, ensure it is clean before sampling, then at each sampling point, dig to expose a smooth face of soil, the width of the spade and to the depth of cultivation. From this face, remove a slice of soil not more than one inch thick from the whole depth of the exposed face and put it in a clean bucket. All samples from a given section should then be mixed thoroughly in the bucket and the mixed sample reduced by repeated halving until about 2 lb/*1 kg* soil is left. This should be put in a strong polythene or hessian bag—the best size is one which the sample will fill half to two-thirds full.

*Note.* For further reading please see the end of Chapter 5, page 39.

# Chapter 4
# PLANT NUTRIENTS – FERTILISERS AND MANURES

## Introduction

The regulation of a balanced supply of nutrients is one of the nursery manager's most important duties. No one nutrient can be said to be more important than another for plant growth, though in any particular nursery, one nutrient may be in shorter supply than another because of the local soil type or climate.

Besides carbon dioxide and water, young forest trees require in assimilable form nitrogen, phosphorus, potassium, magnesium, calcium and sulphur, and at least traces of seven other elements. The four elements first mentioned have to be applied deliberately in adequate amounts, otherwise crops may fail. Calcium and sulphur may not occur naturally in sufficient quantities for good plant growth, but are constituents of such fertilisers as superphosphate which contains both calcium and sulphur as well as phosphorus. The other elements also required for plant growth, namely iron, manganese, copper, zinc, boron, molybdenum and chlorine are needed in such small quantities that they rarely have to be considered in any nutrient regime.

*Note:* In this section and subsequently, chemical symbols are regularly used to designate nutrients. These symbols include:

| | | | |
|---|---|---|---|
| Ca | calcium | $NH_4$ | ammonium |
| Cl | chloride (chlorine) | $NO_3$ | nitrate |
| $CO_3$ | carbonate | Na | sodium |
| Cu | copper | P | phosphorus |
| K | potassium | $PO_3$ | phosphate |
| Mg | magnesium | S | sulphur |
| Mn | manganese | $SO_4$ | sulphate |
| N | nitrogen | Zn | zinc |

## 4.1 Nutrient Regimes

Inorganic soluble fertilisers form the basis for current maintenance of fertility in nurseries. Recommendations for their use are given in Section 4.2.

In the past there has been considerable controversy about the best way of providing the nutrients necessary to maintain a high output of good quality plants from forest nurseries. The principal issues have been (i) the role of hopwaste and composts in plant nutrition, (ii) the role of crop rotation in maintaining output, (iii) the long-term effectiveness of soluble inorganic fertilisers.

Section 4.5 following summarizes current evidence on hopwaste and other bulky organic manures; they are widely used but rates vary markedly and foresters have to consider whether they are putting hopwaste on the right crops.

Whether land not under forest plants is green-cropped or is maintained under bare fallow has in recent years followed a regional pattern.

Broadly, nurserymen green-crop in Scotland and fallow in England and Wales. Current information is summarized in Section 4.6.

Some results of experiments on the long term effect of inorganic and organic fertilisers are given in Appendix IV.

Some indication of the demands made by full crops of conifers is given in the next paragraph.

TABLE 7

NUTRIENTS REMOVED IN SITKA SPRUCE CROPS (TOPS AND ROOTS) POUNDS PER ACRE**

| Crop and Nursery | Dry Matter | N | P | K | Ca | Mg | Mn |
|---|---|---|---|---|---|---|---|
| *Sitka Spruce Seedlings* | | | | | | | |
| Teindland | — | 50 | 7.5 | 38 | 12 | 4 | 1.5 |
| *Wareham, Dorset | 2910 | 44 | 7 | 20 | 18 | 4 | — |
| *Kennington, Oxford | 3580 | 69 | 11 | 43 | 22 | 4 | — |
| *Sitka Spruce Transplants* | | | | | | | |
| Wareham | 4032 | 63 | 10 | 37 | 22 | 5 | — |
| Kennington | 6720 | 100 | 14 | 60 | 39 | 7 | — |
| Devilla | — | 105 | 13 | 57 | 17 | 7 | 10 |

*Notes:* *See Benzian, B., 1966, *Manuring in Young Conifers. Proceedings of the Fertiliser Society, 94*, page 13.

**To convert to kg per hectare, multiply figures in the table by 1.1.

### 4.11 Nutrients Used by Plants

Forest nursery crops when lifted, leave few residues and the quantity of nutrients removed in foliage, stem and roots is of the same order as is removed in harvesting crops like cereals, hay or potatoes.

Some indication of the quantities of nutrients removed in nursery stock is given in Table 7. What is actually removed by any particular crop will depend on the soil, the size of plants, density of stocking, fertiliser regime and weather. Nevertheless the ratio of various nutrients taken up will be of the order of those in the table.

The figures for nutrients removed must on no account be taken as a close guide as to what needs to be added to maintain a crop. Nutrients are lost by leaching, decomposition or by becoming fixed in the soil, the extent of loss depending on the soil and on the nutrient. In an extreme case of a sand low in clay and organic matter, crops used 23 per cent of the K applied, 7 per cent remained in the cation exchange system, while 70 per cent had been leached from the 17 inches/*42 cm* of profile examined. On the same site, the crop used only 8 per cent of the P applied, 14 per cent remained in the upper 10 inches/*25 cm* of soil while nearly all the rest had been leached down where it was held in the $B_1$ and $B_2$ horizons (Bolton and Coulter, 1966). Soils better furnished with clay and organic matter can be expected to retain higher proportions of nutrients applied.

### 4.2 Recommendations for the Use of Fertilisers in Forest Nurseries

No single set of recommendations is likely to fit all circumstances, nevertheless a range of recommendations can be made for the use of fertilisers. To step outside these ranges is to risk crop failure, or the extravagant and wasteful use of materials.

Table 8 shows the rates of application of N, P, K and Mg recommended for each crop in seedbeds and transplant lines.

Table 9 shows the materials to apply to correct any soil deficiencies in the year following soil analysis.

Table 10 lists some currently available fertilisers and the rates of fertiliser required to provide nutrient in the amounts listed in Table 8. The list in Table 10 is of necessity both incomplete and liable to become obsolete as fertilisers are changed.

### 4.21 N, P, K and Mg Applications Per Crop

The most appropriate rate has to be selected from within the range of rates of N, P, K and Mg recommended in Table 8. Some guidance is given below and in Sections 4.4., 3.3 (soil analysis) and 5.4 (foliage analysis). While the cost of fertilisers is only a small part of nursery costs, obviously the more fertiliser used, the greater the cost, and this is an incentive to limit the use of fertilisers. Otherwise the

TABLE 8

QUANTITIES OF N, P AND K RECOMMENDED FOR SEEDBEDS, LINES AND GREENCROPS
LB PER ACRE/*KG PER HECTARE*

| Crop | Highly Soluble Fertiliser | | | | | | "Enmag" | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | | P | K | | Mg | N | | P | K | | Mg |
| | Applied before cropping | Top-dressing | Applied before cropping | Applied before cropping | Top-dressing | | In 'Enmag' applied before cropping | Top-dressing | Applied before cropping | Applied before cropping | Top-dressing | |
| Seedbeds | — | 45–135 /*50–150* | 50–100 /*55–110* | 90–120 /*100–130* | 0–180 /*0–200* | 35 /*40* | 66 /*72* | 0–90 /*0–100* | 130 /*145* | 90 /*100* | 0–180 /*0–200* | 140 /*155* |
| Transplants following fallow or another tree crop | — | 45–90 /*50–150* | 50–80 /*55–90* | 90–120 /*100–130* | 0–90 /*0–100* | 35 /*40* | 66 /*72* | 0–45 /*0–50* | 130 /*145* | 90 /*100* | 0–90 /*0–100* | 140 /*155* |
| Transplants following greencrop | — | 45–90 /*50–100* | 30–55 /*33–60* | 60–80 /*65–90* | 0–90 /*0–100* | 35 /*40* | 44 /*48* | 0–30 /*0–33* | 90 /*100* | 60 /*66* | 0–90 /*0–100* | 95 /*105* |
| Greencrop | 40–50 /*45–55* | — | 45–60 /*50–65* | 65–85 /*70–95* | — | — | Not Recommended | | | | | |

For organics, see Section 4.5 following

TABLE 9
MATERIALS RECOMMENDED TO CORRECT SOIL DEFICIENCIES

| Indications from Deficiency symptoms or Soil analysis | pH below 4.5 | Acidity of soil pH 4.5–5.5 | pH above 5.5 | Notes |
|---|---|---|---|---|
| Low in P | Ground mineral phosphate and ground limestone or chalk | Ground mineral phosphate | Ground mineral phosphate | For rates, see Section 4.42 |
| Low in K | (Apply higher rates of soluble K fertiliser to each crop either in spring or as top-dressing according to soil type and rainfall) | | | For rates, see Tables 8 and 10 |
| Low in Mg | Magnesian limestone | (Apply Epsom salts or Kieserite or "Enmag" for each crop) | | For rates, see Tables 8 and 10 and Sections 3.33 and 4.45 |
| Nutrient reserves satisfactory | Magnesian limestone or lime. See Sections 4.44 and 4.45 | — | Sulphur or ammonium sulphate etc. See Section 4.47 | |

TABLE 10
SOME FERTILISERS COMMONLY USED IN FOREST NURSERIES

| Fertiliser | Declared Analysis | | | | Lb of Nutrient per cwt | | | | Kg of Nutrient per 100 kg | | | | Rate of Use cwt per acre/ *Kg per hectare* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N % | $P_2O_5$ % | $K_2O$ % | MgO % | N | P | K | Mg | N | P | K | Mg | |
| **PK Fertilisers** | | | | | | | | | | | | | |
| Fisons Double season PK | | 20 | 20 | | | 10 | 19 | | | 8.8 | 17 | | 5–8 */600–1000* |
| SAI* "Potassic supers" | | 19.5 | 10 | | | 9.6 | 9 | | | 8.6 | 8.3 | | 5–8 */600–1000* |
| **NPK Fertilisers** | | | | | | | | | | | | | |
| "Enmag" | 5 | 24 | 10 | 16 | 5.6 | 12 | 8 | 11 | 5.6 | 10.6 | 8.3 | 10 | 10–11 */1300* |
| Fisons Double season 55 | 8 | 20 | 16 | | 9 | 10 | 15 | | 8 | 8.8 | 13 | | 4½–5½ */600* |
| **N Fertilisers** | | | | | | | | | | | | | |
| "Nitro-chalk" | 21 | | | | 23.5 | | | | 21 | | | | 1–2 */125–250* |
| Ammonium sulphate | 21 | | | | 23.5 | | | | 21 | | | | 1–2 */125–250* |
| **K Fertilisers** | | | | | | | | | | | | | |
| Potassium sulphate | | | 50 | | | | 46 | | | | 42 | | 1–2 */125–250* |
| Potassium chloride (muriate of potash) | | | 60 | | | | 56 | | | | 50 | | 1–1⅔ */125–200* |
| **NK Fertilisers** | | | | | | | | | | | | | |
| "Kaynitro 25" | 25 | | 16 | | 2 | | 15 | | 25 | | 13 | | 1–2 */125–250* |
| **Mg Fertilisers** | | | | | | | | | | | | | |
| Epsom salts | | | | 17 | | | | 11.5 | | | | 10 | 3–5 */400–600* |
| Kieserite | | | | 29 | | | | 19.5 | | | | 17 | 2–3 */250–400* |
| Magnesian limestone** | | | | | | | | | | | | | Depends on pH of Soil and Mg content |

*SAI = Scottish Agricultural Industries, Ltd.

**Up to 23% MgO (15% Mg.)

chief disadvantage of selecting higher rates of fertiliser is the increased risk of fertiliser scorch. See Section 5.2.

In Table 8, the lower rates of P and K recommended under "Highly soluble fertiliser" represent what has been widely used in many nurseries in the past. The higher rates should be used if the soil is low in P or K.

Transplants following a well-manured greencrop normally require about two-thirds of the P and K that would be applied if they followed fallow or another tree crop.

The lower rate of N recommended is for those species such as larch, alder and Douglas fir which respond to heavy N dressing by growing too tall. The usual rate of nitrogen for most species is 90 lb N per acre/*100 kg per hectare* (such as is applied in two top-dressings of 2 cwt per acre/*250 kg per hectare* of "Nitro-chalk"—21 per cent N.

Magnesium should be applied or "Enmag" used where crops have shown magnesium deficiency. If soils are also low in K, additional K should be given by top-dressing rather than by heavier applications of "Enmag".

### 4.22 Materials to Correct Soil Deficiencies

Table 9 names materials to be used to correct soil deficiencies. The choice of materials depends on soil pH, and rates have to be related to the extent that corrections are necessary.

If the pH is low, magnesian limestone is to be preferred to chalk or ground limestone. If the pH is low and soil Mg is low, magnesian limestone should be insisted on. See also Section 4.45.

High grade Bessemer basic slag has been recommended in the past as a means of raising both the pH and the phosphate status of soils. However, it is a variable by-product in an industry that is continually modifying its production processes and it is preferable to use the well proven ground mineral phosphate and ground limestone or chalk rather than a material of uncertain specification.

## 4.3 Timing of Fertiliser Applications

Granular fertilisers can feasibly be spread at any time of the year. If they are spread after seedbeds have been sown, or transplants lined out, i.e. applied as a top-dressing, they usually remain on the soil surface until dissolved and carried in solution into the soil

Applications before the crop is on the ground can be incorporated into the upper soil by ploughing or rotovating. This is the normal practice with potassic superphosphate, magnesium fertilisers and materials to correct low pH or phosphorus deficiency in the soil.

The principal disadvantage of incorporating soluble fertiliser in winter or early spring is that a proportion of it is likely to be lost by leaching before the crop can reach it. This is particularly true of nitrogen, which is therefore normally applied as top-dressings.

The principal disadvantage of top-dressings is that insufficient rain may fall after their application for them to be carried deeply into the soil. The resultant high concentration of salts near the surface can damage plants. (See Section 5.2, fertiliser scorch).

In particular for K, the soil and climate should determine practice. If soils are loamy and rainfall is moderate, K applied in the spring should last the whole growing season without the need for top-dressing. If soils are light and especially if they are low in organic matter, it is better to put on a standard dressing of K in the spring and to add extra K as top-dressing during the growing season.

### 4.31 Application of Fertilisers Before Sowing or Transplanting

Potassic superphosphate, "Enmag", Epsom salts etc, should be spread and rotovated or cultivated into the top three to four inches of the soil. As soluble nutrients may be lost by leaching, there should normally be only a short interval between their application and sowing or transplanting. However, on light soils when it is anticipated that seedlings or transplants of salt-sensitive species (Norway spruce and *Abies*) are likely to have to be lined-out late in the season, the risk of fertiliser scorch may be reduced (i) by applying fertiliser about a month before lining-out, or (ii) PK fertiliser should be withheld, hopwaste application doubled (supplying P) and K applied as mid-season top-dressing in periods of showery weather, or (iii) alternatively "Enmag" may be used.

### 4.32 Top-dressings

For many years, only nitrogen was given as a top-dressing to seedbeds and transplants. More recently, top-dressings of potassium have proved beneficial especially to crops on light soils because, by increasing the content of K in plants, their potential resistance to early autumn frost is improved and K deficiency, visible or latent, is reduced. The recommended rates of application are given in Table 8.

It is now recommended that for most species growing normally, two N or NK dressings should be given, plus one dressing of NK in late August to early September. On very light soils low in organic matter, the number of top-dressings may need to be increased to four, alternating N and NK.

Certain species respond vigorously to added nitrogen—namely larches, Douglas fir, alder and birch. It may be necessary to give these species the lowest rate of the nitrogen recommended in Table 8 by reducing the number of top-dressings or reducing the quantity applied at each dressing.

There is no advantage in applying highly soluble nitrogen fertilisers before sowing—much will be lost by leaching before the plants are sufficiently developed to benefit.

*Timing of Top-dressings*

For seedbeds, the first top-dressing should be applied five to seven weeks after germination has started. By this time, the primary needles should just have appeared. Subsequently applications should be at three to four week intervals. For transplants, top-dressings should be delayed until at least a month has elapsed after transplanting, but subject to this, the first application should be in mid-May, and subsequent applications at four to five week intervals. At least one inch of rain (in total) should have fallen, or half inch of water have been given by irrigation, between consecutive top-dressings. Avoid top-dressings in hot weather or on very dry soil or when the foliage is damp.

If any dressing is followed shortly after by prolonged heavy rain, most of the dressing may have been lost by leaching and the need for another dressing should be considered.

On crops to be stood over, it is usual to apply one-half of the top-dressings one year and one-half the next.

*Late Top-dressings to Correct Deficiency Symptoms in Growing Plants*

Plants showing any marked deficiency symptoms at the time of lifting should not be sent out for planting. However, late season top-dressings can be applied to correct deficiencies appearing in late summer and thus avoid the possibility of having to hold back plants.

*Nitrogen* An application of "Nitro-chalk" or ammonium sulphate late in the season will usually improve the colour of plants deficient in N. However, such plants often improve in colour through the winter without special treatment.

*Potassium* A late-season top-dressing of 1 to 2 cwt per acre/*125 to 250 kg per hectare* of sulphate of potash may correct potassium deficiency. There is less certainty of uptake of K in the autumn than with N or Mg.

*Magnesium* Epsom salts at 1 to 1½ cwt per acre/*125 to 200 kg per hectare* may reduce or eliminate Mg deficiency symptoms. If applied as crystals, plants have to take up the Mg from the soil. However, plants sprayed in July or August with Epsom salts solution, containing 4 ozs per gallon at 120 gallons per acre/ *25 g per litre at 1300 litres per hectare* have also responded well, and in this instance, it is thought that plants have taken up a small part of the Mg through the foliage.

## 4.4 Notes on Nutrients and the Fertilisers Supplying Them

### 4.41 Nitrogen: N

Nitrogen is taken up by plants as ammonium ($NH_4$) or nitrate ($NO_3$) nitrogen, conifers responding better to the former rather than the latter.

*Nitrogen Fertilisers*

"Nitro-chalk" and "Nitrashell" are both proprietary mixtures of ammonium nitrate and calcium carbonate. The chalk (calcium carbonate) offsets to some extent the acidifying effect of the ammonium nitrate so that the pH is not much altered by their regular use (but see para 3.25). In recent years, the concentration of N in "Nitro-chalk" has been increased from 15.5 per cent to 25 per cent, while "Nitrashell" has been changed from 23 per cent to 26 per cent N by altering the proportion of the two constituents.

"Nitram" is commercial ammonium nitrate with small quantities of additives. "Nitram" contains 34.5 per cent N and is likely to acidify soils more than "Nitro-chalk" but less than ammonium sulphate.

Ammonium sulphate contains 21 per cent N and is a cheap nitrogen fertiliser widely used in agriculture. It acidifies soil and while it should not be used in nursery soils which are already sufficiently acid, it is well suited for nurseries where the soil is not acid enough (Section 3.24). Ammonium sulphate crystals can cake together and it is always advisable both to ensure that the fertiliser is free-flowing when purchased and that it has not lost this property in store.

"Nitro 26", containing 26 per cent N, is a mixture of ammonium sulphate and ammonium nitrate. It is likely to acidify soil but not so strongly as ammonium sulphate.

"Nitro-chalk" or its equivalents, and ammonium sulphate have formed the mainstay of current practice in forest nurseries for many years.

Nitrogen fertilisers tested in experiments include ammonium nitrate, calcium nitrate, urea, crushed hoof, dried blood, formalized casein, formalized urea, oxidized coal and ammonium alginate; these are described in Bulletin 37, pages 48–63, while more recent experiments have included magnesium ammonium phosphate, isobutylidene diurea (Benzian, 1967); .880 ammonia, and plastic or sulphur coatings for materials like "Nitro-chalk".

### 4.42 Phosphorus: P

1 unit $P_2O_5$ = 0.44 unit P.

The terms phosphate and phosphatic fertiliser are also widely used when discussing P nutrition. Analyses of fertilisers are commonly given in terms of $P_2O_5$ in order to conform with the Fertiliser Act, 1950.

*P and PK Fertilisers*

In practice, "potassic superphosphate", a fertiliser applying both P and K has been used as the main source of P for forest crops. Potassic superphosphate is a mixture of potassium chloride (muriate of potash) and "single" and "triple" superphosphate. Being a mixture, different manufacturers market different blends. In the recent past, different manufecturers have simultaneously marketed PK fertilisers in which the ratios of $P_2O_5$ : $K_2O$ were 1 : 1, 1 : 2 and 2 : 1. (In terms of P : K, the ratios in the same fertilisers are approximately 1 : 2, 1 : 4 and 1 : 1 respectively).

Over the years, the declared analysis in terms of per cent $P_2O_5$ and $K_2O$ in these and most other inorganic fertilisers has risen while the ratio of the nutrients has remained the same. For example the content of Fisons 1 : 1 ratio fertiliser has altered from a compound containing 13 per cent $P_2O_5$ : 13 per cent $K_2O$ to one containing 20 per cent $P_2O_5$ : 20 per cent $K_2O$—by partly replacing "single" with "triple" superphosphate.

Compound fertilisers with the 1 : 1 and 2 : 1 ratio of $P_2O_5$ : $K_2O$, have been the mainstay of fertility regimes in forest nurseries for many years.

When applied in early spring, the supply of potassium from potassic superphosphate does not last the summer on light soils low in organic matter —especially in wet seasons; the phosphorus has, however, usually remained available for the full growing season. This difference is due to the superphosphate being much less soluble than potassium salts, which are lost by leaching on non-retentive soils.

It is unwise to rely on residues of potassium or phosphorus being available more than 12 months after any given application. For each new crop (seedlings or transplants) fertilisers containing P and K should be mixed in the surface layers of the soil shortly before sowing or lining out.

Bulletin 37 includes accounts of experiments with basic slag, North African ground mineral phosphate (G.M.P. or "Gafsa"), superphosphate, triple superphosphate, di- and tri- calcium phosphate and bonemeal. More recent work has included fertilisers providing more than one major nutrient, i.e. magnesium ammonium phosphate and potassium metaphosphate (Benzian, 1966).

*"Enmag"*

Magnesium ammonium phosphate, mixed with potassium sulphate as in the proprietary compound "Enmag", has been used successfully in forest nurseries as an alternative to potassic superphosphate. The magnesium ammonium phosphate constituent is less soluble than most other commercially available inorganic fertilisers, especially when compared with any other containing nitrogen. Whereas highly soluble nitrogen fertilisers are to some extent wasted when applied in the spring since much of the nitrogen may be leached out before the plants can take it up, magnesium ammonium phosphate provides a supply of nitrogen which lasts from the time of application in the spring through much of the growing season. Thus where "Enmag" is used, the first nitrogen top-dressing that otherwise would be applied can be omitted. However, the supply does not usually last the full season and a top-dressing in July or later often may be desirable.

Table 10, page 23 gives the analysis of "Enmag" and illustrates that four or five times more magnesium and at least twice as much phosphorus is applied when using this fertiliser compared with the highly soluble inorganic materials. It is not yet known what the long-term effects of the repeated use of "Enmag" will be though there are indications that it will raise rather than lower the pH of the soil.

### 4.43 Potassium: K

1 unit $K_2O$ = 0.83 unit K.

*Potassium fertilisers*

Two compounds including K, potassic superphosphate and "Enmag", have already been fully described in Section 4.42.

Potassium chloride (muriate of potash) and potassium sulphate are seldom used by themselves in forest nurseries but are constituents of both materials just mentioned. However, either would be suitable for a late season top-dressing if K alone was required.

Potassium metaphosphate ($KPO_3$) has been tested quite extensively in experiments. On the lightest soils, it has sustained a supply of K better than potassic superphosphate but was not as effective in maintaining high concentrations of K as was a regime of potassic superphosphate in the spring plus a top-dressing of K (prilled potassium nitrate) in the summer (Benzian, 1967). At present, it is not available commercially.

Few other materials have been tested in experiments. Glauconite, in trials, was not as consistent as soluble forms (Benzian, 1965).

Fertilisers supplying N and K together have been in general use in forest nurseries since about 1963 and are mixtures of highly soluble salts, originally ammonium sulphate and potassium chloride; more recently, ammonium nitrate has been used in some mixtures. Particular mixtures such as "Kaynitro 25" (25 per cent N; 16 per cent $K_2O$) are suited to top-dressing both beds and lines, and may be used to give additional K where ammonium sulphate or "Nitro-chalk" has been used in the past.

Agricultural grade potassium nitrate has only recently been put on the market and is not yet widely used in Britain.

If any NK fertiliser is used instead of "Nitro-chalk", the soil may be acidified. This can be detected and must be corrected at any subsequent routine analysis for soil pH.

When using NK compounds as top-dressings, particular care has to be taken to avoid scorch or damage to plants, either by uneven distribution, by lodging of granules on foliage and in leaf axils or by overdosing. They must not be applied in periods of drought.

### 4.44 Calcium or Lime: Ca

Calcium is the principal constituent of almost all materials used for raising soil pH. (Section 3.23). Most soils contain plentiful reserves of calcium; in addition, calcium is a constituent of "single" superphosphate and of "Nitro-chalk" etc. It is only on the lightest and most acid sandy soils that the additional Ca from such fertilisers may supplement the soil reserves.

At present, calcium is nowhere prescribed as an essential nutrient to be deliberately added, nor is this likely in the foreseeable future.

### 4.45 Magnesium: Mg

1 unit Mg O = 0.60 unit Mg.

*Magnesium Fertilisers*

There are four sources of Mg commonly added to forest nursery soils. Two of these contain magnesium sulphate: Epsom salts (10 per cent Mg) includes just over 50 per cent, by weight, of water combined in the dry crystals, while Kieserite (17.5 per cent Mg) contains a little less than 10 per cent of water. Either material is suitable for use annually on forest crops. Magnesium sulphate in solution can be sprayed onto crops in the autumn in an attempt to rectify magnesium deficiency symptoms (see Section 4.32).

Magnesium ammonium phosphate is discussed in Section 4.42.

Magnesian limestone and dolomitic limestone are discussed in Section 3.23.

### 4.46 Zinc and Other Heavy Metals

Stunting and even death of seedlings can be caused by zinc from galvanised iron and more particularly from galvanised wire netting. There are many instances of rolls of galvanised wire netting, especially new wire, causing damage to seedbeds.

In all cases where foliage has been analysed, affected plants have had about twice the zinc content of healthy plants; the maximum concentration which plants have tolerated has been about 300 ppm for Sitka spruce and *Nothofagus*, 600 ppm for Lawson cypress and 900 ppm for *Pinus radiata*.

Other heavy metals, e.g. chromium, nickel and lead are known to be toxic to some plants, but symptoms of toxicity on stock in forest nurseries have not yet been recorded. However, stone from mines and quarries brought in as road metal has sometimes been toxic. Because of the possibility of toxic concentrations of heavy metals, the use of town waste is not recommended in forest nurseries.

### 4.47 Sulphur: S

This important and essential element is applied as an unspecified constituent of many fertilisers. Sulphur deficiency symptoms are not known on the range of soils normally encountered in forest nurseries. Damage due to excessive concentrations of sulphate ions cannot be distinguished from "scorch" symptoms caused by chloride or ammonium ions. However, sulphate ions are the least liable of these to cause scorch. See Section 5.2.

## 4.5 Bulky Organic Manures

In the past, bulky organic manures such as farmyard manure and composts of various sorts were the traditional means of improving soil fertility. In agriculture in the last two or three decades, however, chemical fertilisers have largely supplanted bulky organics. In forest nurseries, farmyard manure and similar materials were discarded soon after 1950. Composts, i.e. bulky organic matter chopped and piled up to ferment for four to eight weeks, were in vogue in 1945–53, following Rayner's discovery of the excellent growth of seedlings on impoverished soil to which composts had been added. Composts in turn have given way to hopwaste which continues to be used in nurseries on light soils.

Organic manures can affect:

The supply of available nutrients (Section 4.51).

TABLE 11

THE AMOUNTS OF N, P, K AND MG ETC IN VARIOUS BULKY ORGANICS
*(From Tables 80 and 81, Forestry Commission Bulletin 37: Experiments on Nutrition Problems in Forest Nurseries, Vol. I)*

| | Per cent moisture content of fresh material | % in dry matter | | | | |
|---|---|---|---|---|---|---|
| | | Organic Matter | N | P (Total) | K | Mg |
| Hops | 84–87 | 85–89 | 4.8–5.1 | 0.9–1.3 | 0.2 | 0.4 |
| Peat | 47 | 93 | 2.1 | 0.0 | 0.1 | — |
| Sawdust | 44 | 99 | 0.2 | 0.0 | 0.1 | 0.0 |
| Bracken-hopwaste compost | 72–81 | 70–83 | 3.2–3.9 | 0.5–0.9 | 1.3–2.1 | 0.3 |
| Straw-hopwaste compost | 73–82 | 66–78 | 3.6–4.3 | 0.9–1.0 | 0.4–0.8 | 0.4 |
| Farmyard manure | 76 | 75 | 2.2 | 0.3 | 2.8 | — |
| Sewage sludge* | 20–55 | 39–42 | 1.6–2.8 | 1.4–2.3 | 0.3–0.4 | — |

*But see Section 4.58, Town Wastes, page 32.

Soil organic matter content and soil physical properties (Section 4.52).
Soil biology (Section 4.53).
The weed population in the nursery (Section 4.54).

**4.51 Bulky Organic Sources of Nutrients**

The nutrient value of organic manures varies widely according to their origin. Table 11 (condensed from Tables 80 and 81 of Bulletin 37) summarises the moisture content and per cent of N, P, K ,Mg and organic matter in the dry matter of a range of bulky organics. Hopwaste is relatively high in N and P but low in K. Peat and sawdust have virtually no P and K, and sawdust has little N either. Bracken/hop compost made using 75 per cent bracken and 25 per cent hopwaste has a ratio of N : P : K well suited to forest nursery crops, while farmyard manure is particularly rich in K.

Not all the nutrients contained in bulky organics are available to crops. Added organic matter, whether as a manure or as a greencrop residue, is broken down by bacteria which themselves can compete with plants for nutrients, in particular nitrogen. This competition can become serious if added organic matter with much woody tissue or with a high C/N ratio is applied; as breakdown proceeds, such materials are likely to deplete rather than add to the available nitrogen in the soil.

**4.52 Bulky Organics and the Organic Matter Content of Soils**

The organic matter content of soils varies from less than 1 per cent in some older forest nurseries in Lincolnshire to 25 per cent or more on soils where peat has accumulated. For most forest nursery soils, the organic matter content lies in the range 2 to 6 per cent.

Very little evidence is currently available on the long-term effects on the soil of cropping with and without bulky organics. The results from two not entirely satisfactory experiments are given in Table 12. This shows the contrasting effect of the sustained use of bracken-hopwaste compost or hopwaste on different soils from two experiments of similar design, one at Bramshill, Hants, on a loamy sand with 10–15 per cent silt and clay, the other at Teindland, Morayshire, on a sandy loam with 25 per cent silt and clay. At both nurseries, 20–24 tons of hopwaste or compost including hopwaste per acre/*50–60 tonnes per hectare* were given annually. At Teindland the soil organic matter on non-experimental land given 12 tons of hops per acre/ *30 tonnes per hectare* every other year was between 11 and 13 per cent.

TABLE 12

PER CENT SOIL ORGANIC MATTER CONTENT IN LONG-TERM TRIALS OF BULKY ORGANICS (HOPWASTE OR BRACKEN-HOPWASTE COMPOST) V INORGANIC FERTILISERS

| Nursery | Organics | Inorganics |
|---|---|---|
| Teindland, Moray, after 11 years | 17 | 9 |
| Bramshill, Hampshire, after 13 years | 4.1 | 3.2 |

These differences typify the contrasting extremes in experience between northern and southern nurseries. When viewed against the just quoted range of organic matter content of between 2 and 6 per cent in many nursery soils, the small difference at Bramshill is of no great significance. The site at Teindland has an exceptionally high organic matter content even on the plots given inorganics only and the result there is relevant to very few other nurseries.

*Effect of Bulky Organics on Soil Physical Properties.* This aspect has also received very little attention. However, one comparison is shown in Table 13 from one of the experiments also quoted in Table 12 and illustrates that at Teindland, where the use of hop-waste resulted in a substantially higher organic matter content, both the moisture holding capacity and the stability of soil aggregates was correspondingly increased.

TABLE 13

EFFECT OF SIX ANNUAL APPLICATIONS OF 24 TONS RAW HOPWASTE PER ACRE ON SOME PHYSICAL PROPERTIES OF A SANDY LOAM SOIL

Teindland Nursery, Moray

| | Organic Matter % | Moisture Equivalent | Micro-aggregate Stability % |
|---|---|---|---|
| Control | 11 | 20.8 | 11.4 |
| Hopwaste | 18 | 29.3 | 15.0 |
| Difference for Significance at 0.1% | 3.7 | 3.4 | 2.4 |

### 4.53 Bulky Organics, Composts and Soil Fungi

In 1945, it was hotly disputed whether the proven value in forest nurseries of the various composts developed by Rayner in her work on factors affecting direct sowings in the forest was due to some biological effect or to their nutrient content. Rayner considered that the stimulation of mycorrhizas (i.e. rootlets growing in intimate association with fungi, to their mutual advantage) was the main function of the composts. Crowther who in 1945 was asked to investigate the reasons for poor growth in forest nurseries, considered the effect to be essentially nutritional. Attempts to find evidence to decide this issue resulted in some of the work described in Bulletin 37, *Nutrition Problems in Forest Nurseries.* This showed that the effect of composts and other bulky organic materials can largely be attributed to its nutrient content.

Levisohn in a paper included in Bulletin 37 gives details of observations on mycorrhizal roots of Sitka spruce seedlings under various treatments and concludes firstly that there is no clearcut difference in mycorrhizal development between plants raised with bulky organics and similar size plants raised with inorganics; secondly that mycorrhizas develop late in the season, sometimes only after the shoots have hardened off for the year; thirdly that the size of plants appears to have some effect, mycorrhizas developing sooner on medium size rather than very large or very small plants. N and P usually stimulate development though very high rates of N do the opposite.

These findings refer to seedlings in nursery soils plentifully supplied with nutrients. For older trees, and in soils where nutrients are deficient, there is abundant evidence that mycorrhizas increase nutrient uptake, though there is little critical evidence on what factors in the environment stimulate or prevent the development of mycorrhizas.

It was not possible to make rigorous comparisons of the forest performance of trees raised in the nursery with and without mycorrhizal roots, largely because of the difficulty of keeping roots free of the association until the normal times of planting. In one trial of autumn planted seedlings, mycorrhizal plants grew better than non-mycorrhizal ones, but even in this instance, the possibility that other differences in the plants were responsible for the effect observed cannot be dismissed.

### 4.54 Bulky Organic Manures and Weed Seeds

Heathland nurseries, at the same time as growing admirable crops on composts, are usually virtually free from weeds. All forms of bulky organic which could introduce weed seed should, obviously therefore, be banned from such nurseries. Farmyard manure, until 1945 used in many nurseries, fell out of use mainly for this reason and other potentially weedy composts incorporating, for example, oat straw were also rejected. The use of bracken-hops compost in most post-war experiments testing bulky organic manures stems from its richness in N, P and K, and freedom from weed seeds.

### 4.55 Growth and Yield of Forest Nursery Crops on Bulky Organics compared with Inorganics

Many experiments in Britain have compared inorganic and organic regimes. 110 short-term experiments comparing the height of Sitka spruce seedlings grown on bracken/hops compost with seedlings raised on inorganics only (Bulletin 37, page 127), showed that the inorganic regimes chosen produced bigger plants in wet seasons and that there was no difference in dry ones.

TABLE 14

MEASUREMENTS OF SITKA SPRUCE CROPS FROM PLOTS CONTINUOUSLY CROPPED AND TREATED WITH INORGANICS OR BULKY ORGANICS FOR TWELVE OR MORE YEARS

| | Kennington | | | Wareham | | | Bramshill | |
|---|---|---|---|---|---|---|---|---|
| | 1954–7 | 1958–61 | 1962–65 | 1954–7 | 1958–61 | 1962–65 | 1950–55 | 1956–62 |
| *Mean height in inches — 1 + 0 seedlings* | | | | | | | | |
| Inorganics | 2.0 | 2.7 | 2.1 | 2.1 | 1.7 | 1.4 | 1.7 | 1.6 |
| Bulky organics | 1.4 | 1.9 | 1.6 | 1.5 | 1.6 | 1.4 | 1.5 | 1.9 |
| Both | 1.6 | 2.6 | 2.1 | 2.4 | 2.3 | 2.1 | 1.7 | 1.9 |
| Neither | 1.3 | 1.2 | 0.8 | 0.3 | 0.5 | 0.5 | 0.9 | 0.9 |
| *Number of 1 + 0 seedlings per square yard* | | | | | | | | |
| Inorganics | 950 | 1000 | 1230 | 1080 | 1000 | 1350 | 730 | 740 |
| Bulky organics | 810 | 830 | 1250 | 980 | 890 | 1280 | 630 | 670 |
| Both | 800 | 890 | 1210 | 990 | 960 | 1240 | 690 | 650 |
| Neither | 1020 | 1040 | 1240 | 1210 | 910 | 1290 | 760 | 720 |
| *Mean height in inches — 1 + 1 transplants* | | | | | | | | |
| Inorganics | 10.9 | 12.4 | 10.7 | 9.0 | 8.9 | 7.5 | No transplants grown | |
| Bulky organics | 10.6 | 13.3 | 11.2 | 8.2 | 9.5 | 8.2 | | |
| Both | 11.0 | 14.2 | 11.7 | 10.0 | 9.5 | 8.5 | | |
| Neither | 8.5 | 8.7 | 8.0 | 3.5 | 4.0 | 3.9 | | |

*Notes.* (1) To convert heights in inches to cm. multiply by 2.54; to convert numbers per square yard to numbers per square metre, multiply by 1.2.
(2) Kennington and Wareham results from Benzian, 1967; Bramshill results from Appendix IV.

In these same experiments, the yield of seedlings averaged 10 per cent less on plots under organic regimes than those without. There were, however, major fluctuations either side of this value and in some seasons, yields were markedly better on organic than other plots; nevertheless in 80 out of 110 observations, fertiliser plots gave the higher yields.

The long-term effects of contrasting regimes have been studied in two complex experiments (Benzian, 1967 a) and several over-simple ones. (Faulkner and MacDonald, 1954; see also Appendix IV).

In no experiment where plots have been cropped continuously, is there any evidence of any serious deterioration following one regime or another, though it should be noted that the amounts of N, P and K applied in the inorganic regimes has been increased during the course of most experiments as deficiencies have been recognised and information from other experiments applied, and that the rate of application of organics has also been raised where necessary.

Some results from long-term experiments are given in Table 14. At Kennington and Wareham, the bulky organic material applied was bracken-hops compost. At Bramshill, it was compost in some years and uncomposted hopwaste in others.

On the two sites on sandy soils, Wareham and Bramshill, a combined treatment gave the best and most consistent height growth of seedlings; on loamy soil at Kennington, inorganics alone not merely sufficed but gave superior growth and yield. The long-term effect on seedling numbers was similar to that observed in short-term experiments.

Growth of transplants was slightly better on plots given both compost and inorganics annually than either alone.

The only evidence of the effects of alternative crop regimes after a long period of a given manuring regime is given in Table 15 and shows that in the long-term comparison at Bramshill nursery, residues from twelve years' organic treatments supported

TABLE 15

HEIGHT OF SITKA SPRUCE SEEDLINGS IN 1962 ON PLOTS UNTREATED THAT YEAR: BRAMSHILL NURSERY

| Treatment 1950–61 | Height | | |
|---|---|---|---|
| | *Inches* | Cm | |
| Nothing added | 1.0 | *2.6* | |
| Inorganics only | 1.4 | *3.5* | (Standard error, ± 0.12/*0.30*) |
| Organics only | 1.5 | *3.8* | |
| Both | 2.0 | *5.0* | |

slightly better seedling growth than inorganic residues did.

Differences in exchangeable K, Ca and Mg and in the soil organic matter did not appear large enough to account for these observed differences in growth. (See Appendix IV).

*Bulky Organics and Seedling Numbers*

Evidence that the use of bulky organic matter on seedbeds can depress the yield of seedlings is given at the beginning of this section. This effect has been attributed both to fungal damage and to a physical effect. The first postulates that fungi respond to added organic matter; if the fungi are potentially pathogenic, increased damping off and similar losses may be observed. By the same token, if the fungi are potentially antagonistic to damping off fungi, such losses could be reduced. At least one research worker suggests the use of organic matter to control damping off, but more workers have observed that green manures or composts increase damping off. (For references, see end of Chapter 5, page 39).

The suggestion that organic matter may have a harmful physical effect arises from observations on light soils that large quantities of bulky organics have made it much more difficult to consolidate seedbeds satisfactorily before sowing.

### 4.56 Costs of Bulky Organics

Hopwaste has mostly been obtained for between £1 and £2 per ton delivered. The cost of bracken-hops in 1955 was about £7 per ton, the cost of mixing and turning compost being an appreciable part of this sum.

Rates of application of hopwaste in recent years have mostly varied from 5 to 15 tons per acre, ranging up to 30 tons/*12-36-72 tonnes per ha.* Hops cost from £1.50 for 5 tons to £21.50 for 15 tons; bracken-hops compost at 20 tons per acre costs about £140 per acre. For comparison, inorganics cost from £10 to £20 per acre (*Hopwast at £22–£55, bracken hops at £350 and inorganics at £25–£50 per hectare*).

### 4.57 Summary and Recommendations

In the short term, bulky organics may be considered as sources of nutrients albeit variable in composition. It is feasible to raise seedlings on organics alone; this is expensive and yields over a period are likely to be approximately 10 per cent lower than under an inorganic regime producing seedlings of the same size. Transplants also may be grown as well under organics as inorganics. Survival is not affected either way.

The very scanty long-term evidence is that the use of bulky organics provides some benefit, derived primarily from organic residues, and probably through the build up of nutrient reserves in the soil.

Taking all considerations together, the following recommendations can be made if the nursery manager decides to use bulky organics:

(i) Hopwaste is a well proven material providing N and P and is weed free; if available it is to be preferred over other bulky organic materials. (Section 4.58 contains notes on other materials). If stored at the nursery, it should be kept under a sheet or other cover to minimise loss of nutrients by leaching.

(ii) While in the past, more hopwaste has been recommended for seedbeds than lines, there is a case, illustrated by Table 14, for reversing this practice and putting most or all on transplant lines and little or none in seedbeds, provided the manager is satisfied that he can make up by one or two extra top-dressings to seedbeds, the N that would have been applied in the hops, and by adding 45 lb/*50 kg* more P per acre/*ha* when fertilising seedbeds at the start of the growing season.

If this argument is accepted, apply 10 to 15 tons of hops per acre/*25 to 40 tonnes per hectare* on lines and none on seedbeds. If past practice must be continued, apply 10 tons of hopwaste to seedbeds and 5 tons to lines per acre/*25 and 12.5 tonnes per hectare* respectively.

### 4.58 Notes on Bulky Organics

Some details of the nutrient content of some bulky organics are given in Table 11.

*Hopwaste*

This is a waste product from the brewery where the hops are boiled to extract flavouring. Hopwaste may be applied direct to the soil; there is no benefit from composting hopwaste. Hopwaste is recommended at rates which assume a moisture content of about 80 per cent; some merchants supply "pressed" hops or hopwaste from which about half the water has been squeezed out. This should be applied at three-quarters the rate for unpressed hops.

*Bracken-hopwaste compost*

This material has been discussed in previous sections. It is weed free and provides much N, P, K and some Mg. It is however very expensive to make. Nevertheless, should any nurseryman wish to use bulky organics exclusively, bracken-hopwaste compost at 20 tons per acre/*50 tonnes per hectare* is to be preferred to other bulky organics.

The compost is best made and stored under cover. An earth floor will do but ideally the floor should be hard and draining in such a way that any seepage from the heap can be collected and returned to it.

Hopwaste is used as supplied from the brewery. Bracken should be cut in July, just as the tips of the fronds are uncurling; it should then be chaffed into pieces not more than one to two inches/*2.5 to 5 cm* long. Bracken and hopwaste are then built up into a heap in layers, three parts by volume of bracken to one volume of hops. Sufficient water should be added to moisten the bracken but not so much that water runs off the heap. The heap may then be covered with a layer of straw or bundles of unchaffed bracken. Fermentation should commence almost immediately and a temperature of between 50°C and 60°C in the heap should be reached within seven to ten days. Once the temperature inside the heap begins to fall, any covering of straw or bracken should be removed and the heap turned. If at all dry, further water may be added at this stage. After turning, the heap should again warm up to nearly the same temperature as before. No further treatment is necessary; once cool, the compost is ready for use, though in practice it is seldom needed until early autumn. The heap is likely to lose about one-third of its original volume while composting. Other materials may be composted in a similar way.

*Bark Chippings, Sawdust, Seaweed and Town Wastes*

Organic residues such as bark chippings and sawdust contain much woody tissue and deplete the supplies of available nitrogen in the soil while they are breaking down. They are not recommended for *forest* nurseries.

Seaweed contains much N and K and some P, but also up to two per cent of common salt, and has sometimes caused damage when used as a source of organic matter in nurseries. The damage is due to the salt.

Composts based on town waste are very variable from batch to batch and may contain harmful quantities of heavy metals such as zinc and chromium. There is often also an appreciable amount of broken glass. Composts based on town waste should, therefore, never be used in forest nurseries. Sewage sludge also often contains undesirable materials and is not recommended.

*Peat*

Acid peat has been used only occasionally as a supplement to forest nursery soils. In one nursery on a heavy textured soil, it is considered to have improved the working properties of the soil and also to have acidified it.

*Farmyard Manure*

This material was formerly widely used in forest nurseries. It has been rejected completely for use in clean heathland nurseries because of the weed seeds contained in the manure. Occasionally in the past, too, appreciable quantities of lime have been mixed with farmyard manure; such inadvertent addition of lime could depress growth on all but the most acid soils.

*Broiler House Litter*

This has been used successfully in at least one forest nursery. There are two risks, however. Firstly, in one instance when supplied fresh and left to rot in the nursery, sufficient ammonia was generated to scorch plants within a 20 yard radius of the heap. Secondly, the litter varies in the content of sawdust or wood chips mixed up with the droppings. The more woody matter present, the more resistant the litter will be to complete breakdown.

### 4.6 Rotation of Crops and Greencropping

Forest nurserymen in the inter-war period generally practised a rotation of crops including a greencrop; Guillebaud (1937) described it as a textbook practice borrowed from agriculture. In agricultural conditions, rotational cropping is a soundly based practice. For example, if cropped repeatedly without a break, the yield of cereals decreases progressively due to increases in soil-borne diseases such as "take-all" caused by the fungus, *Ophiobolus graminus*, while repeated cropping with some legumes may lead to soil conditions such as that called "clover-sickness", caused by parasitic fungi and nematodes. Diminished yields of cereals and "clover-sickness" can be avoided by appropriate rotations of crops.

In the mid-1940's, production of Sitka spruce seedlings in many older forest nurseries was poor in contrast to the out-turn from the then newly discovered heathland nurseries and it was thought that the older nurseries might be "Sitka-sick". However, the evidence of many years' subsequent investigations showed that the reason for the poor growth of Sitka spruce were usually that the soil pH was too high, that the supply of nutrients was inadequate, and that nurseries had become excessively weedy. The influence of rotation and greencropping is likely to be relevant only inasmuch as these practices influence the nutrient supply.

**Experiments and practical experience have failed to show any evidence of any harmful consequences of continuous cropping with Sitka spruce seedlings, given adequate nutrition and a suitably acid soil.**

Unlike the specialised parasites of many agricultural crops, the known fungal pathogens of tree seedlings such as species of *Pythium*, *Rhizoctonia* and *Fusarium* have a very wide host range and their incidence is not greatly affected by crop rotation.

There is one minor exception to this claim that there is no clear biological need for a rotation in forest nurseries. Western red cedar seedlings and transplants can be infected in the nursery by the fungus disease *Didymascella* (*Keithia*) *thujina* and losses can be very severe. Cross-infection of first year seedbeds from older stock can aggravate losses. One practical method of control is to ensure that there are no sources of infection in the proximity of the nursery, and then to grow one crop through until large enough to go out to the forest, burn all residual plants and leave a year with no Red cedar in the nursery before starting again. See Section 11.26 for further details.

### 4.61 The Need for a Break in Cropping—Fallow or Greencrop

While in present-day conditions, the agricultural justifications for rotation of cropping do not apply to forest nurseries, nevertheless there may be other justifications for a break in cropping; if the need for such a break exists, it then has to be decided whether to keep land fallow or raise a greencrop.

There are two principal justifications for keeping part of a nursery fallow or under a greencrop in any one year, namely, advance work and weed control. Of these, the first is of greater importance and applies independently of how ground is managed during the break in cropping. In contrast, the effectiveness of any weed control programme is affected by the form of management, greencrops hampering good weed control. During a period of fallow, land can also be subsoiled to break up any plough pan.

*Advance Work*

It is very desirable to have land free from tree crops so that transplanting or seedbed preparation can proceed without waiting for land to be cleared. Prescriptions for the proportion of fallow to cropped land are given in the last three paragraphs of Section 1.13.

*Weed Control*

During fallow, most annual weeds can be kept down by herbicides and by hand weeding. However, infestations of perennial weeds which may have developed among seedlings or transplants are best dealt with during a fallow year. See Chapter 10 for methods.

### 4.62 Fallow

Fallowing has been a traditional way of reducing the number of weed seeds, cultivating shallowly as soon as there is a good showing of weed seedlings, or at intervals of four weeks, so that the more rapidly maturing weeds do not set seed before being buried. Cultivation is preferable to chemical spraying because it disturbs the soil, bringing fresh quick germinating seeds to the soil surface.

*Subsoiling During Fallows*

See Section 3.15, p. 13, on plough pans and cultivation.

*Growth on Fallows*

Enhanced growth has frequently been observed on first-year crops on ground which has been fallowed for several years. Russell (1961) notes that repeated drying and re-wetting of soils promotes mineralisation of organic matter and this possibly occurs more markedly on bare soil than with plant cover. However, there has been little difference between adequately manured plants raised following one-year fallow and those following greencrops.

### 4.63 Greencropping

Greencropping was well established in pre-war rotations in forest nurseries. Guillebaud (1937) described greencropping practices current at that time in the Forestry Commission. In England and Wales 75 per cent of the nurseries practised greencropping, and of these, 50 per cent grew lupins (*Lupinus* spp.), 29 per cent mustard (*Sinapsis alba*) and 12 per cent lupins and tares (*Vicia* spp.); the remainder grew a variety of mixed crops, only one including oats in the mixture. In Scotland, eleven nurseries all grew a mixture of oats and tares.

In pre-war practice, it was held that greencrops should receive manures but that conifers should not as these were considered unresponsive. A "long-term fertility trial" set up at Inchnacardoch included comparisons of greencrops and methods of manuring them and also included continuous cropping with conifers (Faulkner and MacDonald, 1954—see references at end of Chapter 5). No attempt was made in that trial to apply manures direct to seedlings or transplants—these crops had to get their nutrient via greencrop residues; those plants on plots cropped continuously or fallowed, received no nutrients directly or indirectly.

1943 saw the beginning of a change, with the creation of the first heathland nurseries. In these, Rayner's composts were applied to each tree crop. Subsequently, nurserymen in England and Wales and to a lesser extent in Scotland began to rely on inorganic fertilisers and manures applied shortly before sowing or lining out as the main source of nutrients for the crop, rather than on organic residues from greencrops of the preceding year. This change was almost everywhere successful.

By 1963, in the Forestry Commission nurseries where the rotation was broken in some way, out of thirty-six in England and Wales, only one used greencrops, while all nineteen in Scotland did. Twelve Scottish nurseries grew oats and tares, six grew lupins, and one grew oats and peas. Most of these were summer crops, ploughed in while the cereal was still green in the ear or when the lupins were just about to flower. For the remainder of the season, the ground normally remained fallow until required. Where two crops were taken however, the second could remain on the ground into the winter. Such crops were usually followed by transplants. On some soils, the greencrop was incorporated as lining out progressed.

One reason for greencrops falling into disuse in the older established nurseries in England and Wales has been the failure to grow the really vigorous crops necessary if weeds are to be smothered and a worthwhile volume of green matter turned in. The past prevalence of cockchafer beetle and the difficulty of controlling this insect other than by fallowing may have been a contributory factor in the period immediately after the war.

*Present Role of Greencrops*

Clearly greencropping was of different and greater significance in the past when the greencrop was the only phase of a rotation receiving added nutrients than it is now when each crop may be given N, P, K and Mg and often hopwaste as well.

### 4.64 Soil Organic Matter and Greencrops

It has been claimed that the incorporation of bulky greencrops improves the humus content of the soil and provides readily available nutrients, especially nitrogen, for the succeeding crop. However, the nitrogen supply can only be increased by the breakdown of the organic matter in the incorporated greencrop, whereas the humus content can only be increased if the organic matter, in part at least, is resistant to breakdown. If the greencrop is dug in while still soft and green, plant tissues are rapidly broken down and most of the nitrate nitrogen thus released will probably be leached away before the tree crop is put in in the following spring. There is also evidence from agriculture that the nitrogen released by a rapidly decomposing greencrop may result not only in the greencrop's decomposition but also in the breakdown of some of the organic matter present in the soil prior to the greencrop. If, on the other hand, the crop is allowed to mature, fibrous matter low in nitrogen formed in the later stages of growth may persist for some time and may even require nitrogen to enable it to decompose.

Preliminary data from long-term experiments comparing three greencropping regimes in two forest nurseries (Wareham, Dorset and Kennington, Oxford) have shown that effects on crop growth in the following year were small. Data on soil organic matter is not yet available.

### 4.65 Greencrops in High Rainfall Areas

On soils which are likely during the spring and summer to be too wet to spray or to cultivate, so that weeds may multiply (not so likely a combination of circumstances with present-day weedkillers as it was before 1960), a greencrop may be grown as a "smother" crop. However, for this effect to be realised, it is essential to have good germination and vigorous growth of the greencrop.

On heavy soils in areas of high rainfall such as West Scotland, an autumn sowing of ryegrass left through the winter may be of value because of its effect on soil structure and drainage. Such sowings must be timed so that the grass is between 3 and 6 inches/*7.5 to 15 cm* when it is being dug in. Lining out into such a greencrop can sometimes start two to three weeks earlier and can be resumed more quickly after rain than if the land is left to lie fallow through the winter. Greencrops may also minimise soil erosion during heavy rain, compared with fallow.

### 4.66 Recommendations for Greencrops

Greencrops must be suited to the pH of the nursery. Mustard is likely to fail if the soil pH is less than 5.5; while this crop has been widely used in the past, it is not recommended. Oats do best at a pH above 5.5 and are likely to fail at any pH less than 5.0. Blue or yellow lupins and also ryegrass grow well at the range of pH optimum for most conifers.

Lupins should be sown in May or June at 3½ cwt per acre/*450 kg per hectare*. This and all other greencrops should be on ground fertilised at rates shown in Table 8. The crop should be ploughed in not sooner than the time flowers first open but before seeds have set. Lupins are more expensive than oats. On very light soils, seedlings of yellow lupins grown as a greencrop have suffered because of excessive uptake of P when grown on ground given superphosphate (Warren and Benzian, 1959).

Oats should be sown in May at 3 to 4 cwt per acre/*400 to 500 kg per hectare* of Yielder or Castleton potato oats. These should be ploughed in when the ears are visible but still green.

Ryegrass has been used either as a summer crop or an autumn crop. The early crop should be sown in April at 30 lb per acre/*33 kg per hectare* of perennial ryegrass or 20 lb perennial and 10 lb Italian ryegrass per acre/*22 and 11 kg respectively per hectare*. It should be mown regularly and ploughed in in late August. The late crop should be sown between ploughing in of any summer green-crop and mid-September, depending on the site. If autumns are mild and the grass is sown too early, top growth of ryegrass can become so luxuriant as to be an embarrassment by the time it should be dug in. See also Section 4.65 above.

*Note*. For further reading, please see the end of Chapter 5 page 39.

# Chapter 5

# NUTRIENT DEFICIENCY SYMPTOMS AND OTHER CAUSES OF DISCOLORATION IN PLANTS

## Diagnosis of the Cause of Discoloration of Plants

In the course of the year, plants exhibit a range of colours. For most plants, these remain within the range of shades of green until tints associated with natural leaf fall develop. A few species adopt a more bronzed or purple hue over winter, namely Western red cedar and seedling pines, but for most species the untimely appearance of red or yellow hues or browning of foliage is a sign of distress due to one, or a combination of the following:

| | |
|---|---|
| Nutrient deficiency | Waterlogging of Soil |
| Nutrient excess (fertiliser scorch) | Drought |
| Damage by: frost | Sunscorch |
| Damage by: insects | Pesticides (residues or faulty application) |
| Damage by: fungi | |

The first step in determining the cause of any discoloration is always to dig up and examine carefully a sample of the affected plants, paying particular attention to the roots. Possible causes of observed symptoms are:

| *Observed Symptoms* | *Possible Cause* |
|---|---|
| Withering or drying (green) foliage. | Weedkiller; sun scorch; fungal attack; insect feeding on roots. |
| Straw or light-brown foliage (not autumn colours of deciduous species). | Fertiliser excess; weedkiller; heat scorch; fungal attack; copper deficiency. |
| Yellow, red or purple discoloration; foliage remains fresh. | Nutrient deficiency; root damage; lime-induced chlorosis; weedkiller. |
| Spotting or blotching of foliage. | Fungal attack; insect attack; weedkiller. |
| Dead roots. | Waterlogging; fungal attack; bad lining out; maltreatment before lining out; insect feeding. |
| Visible loss of bark on roots, stem, or loss of foliage. | Insect attack; mechanical damage by implement; hail. |
| Dead root collar (or stem at soil surface) but roots and stem healthy. | Weedkiller; sun scorch; fungal attack. |

Pests and diseases and effects of climate are discussed fully in Chapter 11. Symptoms of damage due to the weedkillers used in forest nurseries are described for each weedkiller in Chapter 10. Nutrient deficiencies are discussed in Section 5.1, fertiliser scorch in Section 5.2 and the relationship between fertilisers and frost in Section 5.3.

### 5.1 Nutrient Deficiencies and Their Symptoms

*Note.* In the sections that follow, colours are described using the Munsell definitions and notation.
(*Munsell Color Charts for Plant Tissues.* 1st Edn. 1952. Munsell Color Co Inc, Baltimore 2, Maryland, U.S.A.).

Plants markedly deficient in one or more nutrients show this by poor growth; needles may be smaller than normal and in certain extreme cases, shoots may die back. In addition, plants may be more susceptible to damage by frost, drought, insect and fungal attack.

Symptoms of deficiencies may appear as yellow or red tints or even death in foliage normally green. Spruces exhibit the fullest range of colour deficiency symptoms, hues in Norway spruce being somewhat yellower than those in Sitka spruce. Symptoms of nutrient deficiency of Sitka spruce are described below and are illustrated admirably in plates 3–18 of Vol. I of Forestry Commission Bulletin No. 37, *Nutrition Problems in Forest Nurseries.*

While it is easy to ascribe symptoms to deficiencies induced in experiments, it is not always easy to make correct diagnoses from foliage symptoms alone, as more than one nutrient may be lacking. Diagnosis usually involves weighing up probabilities, taking into account: what fertilisers have been put on and when; the rainfall in relation to applications; soil characteristics; and, if possible, knowledge of the situation with similar crops in other nurseries. Analysis of nutrients in foliage or shoots or whole plants can assist diagnosis of deficiencies (see Section 5.4).

Discoloration similar to deficiency colours may sometimes also be induced by too great a supply of nutrients, especially if the ratio of one element to others is much higher than usual (see Sections 3.3 and 5.2).

## Nutrient Deficiency Symptoms

### 5.11 Nitrogen

Nitrogen deficiency can be observed on most species raised for forest planting.

Foliage of deficient plants is yellow-green and needles are sometimes undersize. Leaves in full sun may be more affected than those partly shaded by other leaves. Spruces show a slight tint of pink on needles at ends of shoots. Seedbeds are sometimes "saucered", i.e. seedlings at edges of bed are taller (and greener) than those in the centre.

N-deficiency colours on Sitka spruce: Munsell 2.5 G7 6/6—5.0 G7 5/6 6/8; pink tints 7.5 R 5/4.

### 5.12 Phosphorus

The principal symptom of P deficiency is the failure of plants to grow in spite of healthy foliage and roots. Sometimes plants are somewhat duller than usual; there is no characteristic deficiency colour.

### 5.13 Potassium

Spruce seedlings and to a lesser extent transplants, first develop purple needles in mid-summer on current growth (10 RP 3/6, 4/4, 5/6; 2.5 R 3/4). This may become more intense but is likely to turn to red or yellow (5.0 R 4/6, 7/8 or 2.5 Y 8/8, 8/10, 9/8 or 5.0 Y 9/10); see plates 6, 8, 13 and 14 of Bulletin 37.

Newly lined-out K-deficient Norway spruce seedlings may be maroon red or chocolate brown in colour. Norway spruce transplants at the end of the season may develop a conspicuous yellow tuft of needles around the terminal bud. If K-deficiency is marked, a few needles may turn brown.

In other species, K deficiency may appear as yellowing of the tips of needles.

### 5.14 Magnesium

Deficiency symptoms appear late in the season—July or after. Spruce needles turn yellow with little transition between the green and yellow parts of the needles; see plates 7, 9 and 15 of Bulletin 37. Munsell colours: 5.0 Y 9/10 to 7.5 Y 8/8 or 9/8. These are greener than the yellow associated with K deficiency.

Young needles may be wholly affected. Older needles become yellow only towards the tip. When severe, needles at the bud of spruce seedlings and the bud itself may turn brown: such browning often appears at the time of the first autumn frosts.

Lodgepole pine seedlings are particularly sensitive to Mg; deficient plants develop needles with bright yellow tips, often with a short but distinct zone of bright red tissue between the yellow and green parts of the needle.

Spruce, pine and fir transplants deficient in Mg may develop yellow tips to needles without any red zone.

The absence of purpling and of warm red-yellow hues helps to distinguish K from Mg deficiency, and the lack of saucering and late development of Mg deficiency colours help to discriminate between Mg and N deficiency.

### 5.15 Copper

Symptoms of this deficiency are rare. Spruce seedlings and transplants and to a lesser extent Western hemlock seedlings develop "tip-burn" or browning of the top half or third of the needle. This damage appears almost overnight in periods of hot, sunny weather in August. Day temperatures of 27°C or more are usually necessary for tipburn to become severe. Healthy needles of affected plants may be arranged in an abnormally accentuated spiral twist near the bud. (Plates 16–18, Bulletin 37).

In general practice, usually, hopwaste provides sufficient copper for plants not to show symptoms when growing on inherently copper-deficient soils. Copper deficiency can be avoided by spraying with Bordeaux mixture at the rate of 75 gallons per acre/ *800 litres per hectare.*

### 5.16 Iron

Lime-induced chlorosis (iron deficiency) is a well-known disorder of plants that prefer acid soils, when they are planted on alkaline soils. The occurrence of this deficiency in forest nursery crops is a strong indication that the site is unsuitable and that a more acid soil should be chosen.

## 5.2 Damage Due to Fertilisers

There are two sorts of damage caused by fertilisers. Firstly, where the individual particles or granules of fertiliser come into direct contact with plant foliage or stems and remain there for a day or more, local patches of brown tissue develop where the fertiliser has lodged. This 'scorch' or 'burn' by fertilisers can occur on any species and may be associated with any form of nitrogen or potassium top-dressing. It can be readily avoided by ensuring that fertilisers are distributed evenly, that plants are brushed to dislodge granules caught in leaf axils etc, and that fertilisers are not applied when foliage is damp so that granules stick.

The second form of damage occurs when high concentrations of certain nutrients are present in the soil; it is usually associated with a spell of dry weather and/or excessive fertiliser dressings. The usual symptoms are that plant foliage turns reddish brown, large or small groups of plants sometimes being affected. Often a pattern of damage can be observed which is related to the means of spreading nitrogen or NK top-dressings. On conifers, symptoms appear on the upper current shoots first. Hardwoods, especially maples, develop a brown margin all round the leaves. Most species can be affected in this way, particularly where fertilisers have been distributed unevenly.

While most fertiliser scorch occurs following top-dressings, Norway spruce and *Abies* species may be damaged when late transplanting into freshly fertilised ground is followed by a period of dry weather. In this instance, the damage is due initially to the chloride present in the potassic superphosphate. See Section 4.31 for recommendations to minimise such damage. Very occasionally in late June and July, in seasons with a dry early summer, Norway spruce has developed brown foliage and Sitka spruce some yellowing, associated with the superphosphate component of potassic superphosphate. See Section 4.58, Broiler House Litter, p. 32.

## 5.3 Nutrient Supply and Frost

It has been generally believed that if late applications of nitrogen prolong the growth of forest nursery stock, frost susceptibility may be increased. However, the evidence in forest nurseries in recent years is that applications of nitrogen in late August or September when growth has nearly ceased, have not in practice increased susceptibility to autumn frost. On the contrary, in at least one season, plants top-dressed with N in late August were more resistant to autumn frosts than untreated plants. Late-season applications of K have been even more effective in inducing frost resistance. Heavy late-season applications of N may however cause plants to flush slightly earlier the following spring with a correspondingly increased risk of spring frost damage.

Suitable rates of N and K for late-season top-dressings are given in Table 8 and are the same as for those at mid-season.

## 5.4 Analysis of Plants

A chemical analysis of the nutrient content of foliage or roots reflects partly the nutrients available in the soil and partly the ability of plants to extract and translocate them. The nutrient content of any part is not constant however but changes as plants grow, mature and age. For example, the K content of Sitka spruce seedlings can fall during the season from 3 per cent of dry matter in mid-summer to 1 per cent or less by late autumn; it can also vary markedly from one season to another (Benzian *et al*, 1969).

Whole plants or parts may be analysed. In an analysis both of whole plants and of tops (or shoots) and roots of Sitka spruce separately, differences of up to 20 per cent in nutrient concentration in the dry matter have been found; in comparisons in three years, shoots had more P, K and Ca than roots but, in two years out of three, less Mg. Forestry Commission analyses have mostly been of needles only. (In this context "shoot" or "top" means all the plant above root collar, while "root" means that part of the root system recovered when the ground is loosened by fork or spade and plants gently shaken out).

TABLE 16

RANGE OF EXPECTED VALUES FOR END-OF-SEASON ANALYSIS OF NEEDLES OF 1 YEAR-OLD SEEDLINGS

| Content of | Nitrogen | Phosphorus | Potassium | Magnesium |
|---|---|---|---|---|
| *Species* | | *per cent Dry Weight* | | |
| Scots pine .. | 1.8–2.5 | 0.17–0.24 | 0.60–0.80 | 0.08–0.12 |
| Corsican pine .. | 1.8–2.5 | 0.20–0.25 | 0.65–1.0 | 0.09–0.12 |
| Lodgepole pine .. | 1.8–2.2 | 0.19–0.26 | 0.7 –1.0 | 0.09–0.12 |
| Sitka spruce .. | 1.3–2.2 | 0.18–0.26 | 0.7 –1.3 | 0.08–0.15 |
| Norway spruce .. | 1.5–2.4 | 0.20–0.30 | 0.5 –0.8 | 0.09–0.17 |
| Douglas fir .. | 1.6–2.4 | 0.24–0.27 | 0.80– 1.1 | 0.07–0.16 |
| Western hemlock .. | 1.6–2.3 | 0.23–0.30 | 0.7 –1.3 | 0.08–0.16 |

*Note:* These ranges have been derived from nutrient analysis data from needles of crops raised in 1966–68 at research nurseries in the South of England. The limits of the ranges define the lower and upper limits to be expected in normal crops. If the results of analysis show seedlings to have a lower N, P, K or Mg content than is given in the table, deficiency symptoms should be expected. Values higher than given in the range can usually be associated with some special treatment of the crop.

### 5.41 The Nutrient Content of Plants

Table 16 summarises the scanty evidence available for forest nursery stock from British nurseries. The values are mostly based on analyses of seedling needles from current shoots taken in late autumn. For Sitka spruce, differences in the concentration of nutrients in needles correlate well with visual symptoms and also agree with data relating deficiencies to the nutrient content of shoot and root. Thus, acute potassium deficiency is associated with concentrations of less than 0.5 per cent K in dry matter of tops; slight symptoms may be seen in plants with 0.6 per cent K. Seedlings with more than 0.7 per cent K are green (unless suffering from some other deficiency). For magnesium deficiency symptoms in Sitka spruce, the threshold value is 0.08 per cent Mg in dry matter of tops and roots (Benzian *et al*, 1969).

Plants may also take up more of a nutrient than is essential for healthy growth without making any extra growth at the time. This phenomenon is known as "luxury uptake" and can be exploited by applying N and K late in the summer when nutrients are still taken up but growth is hardly affected; such plants grow better in the following year than plants not given N or K in that way.

### 5.42 Sampling for Plant Analysis

Ideally, any form of analysis should be arranged so that the results are available in time for remedial action to be taken in respect of the crop sampled. However, foliage analysis as a guide to plant health and nutrition in forest nurseries is in its infancy and at present, results of plant analysis are mainly used to influence the management of subsequent crops.

Before samples are taken, it is essential to discuss with the laboratory making any analysis, what sort of sample is required, how plants should be handled to avoid contamination and when the samples should be taken.

For seedlings, samples should normally consist of at least 20 plants; if a deficiency is suspected, at least four samples should be selected from within the affected crop, two samples of plants showing symptoms and two samples of unaffected or least affected plants. If the deficiency symptom is severe, it is advisable to take two intermediate samples as well.

When any particular nutrient in a sampled crop is found to be low compared with the value given in Table 16, the nutrient regime of the past two or three seasons should be reviewed in relation to the weather, crop growth and deficiency symptoms if any, together with results of any relevant soil analyses. Any logical pattern that emerges should be the basis for deciding whether the rate or timing of application of the nutrient in question should be altered for subsequent crops.

#### FURTHER READING—CHAPTERS 3 TO 5

*Books*

BENZIAN, B., 1965 *Experiments on nutrition problems in forest nurseries*. Bulletin No. 37, Forestry Commission, London. (Vol. I, Text Summary tables and colour plates; Vol. II, Supporting tables). Vol.I of this important work also includes short papers by other workers associated with these investigations; J. E. Brind, J. B. Goodey, D. M. Griffin and I. Levisohn.

COOKE, G. W. 1967 *The control of soil fertility*. London: CROSBY LOCKWOOD and Son.

RUSSELL, E. W., 1961 *Soil conditions and plant growth*. 9th Edition, London; Longmans.

*Papers*

ALDHOUS, J. R. and BROWN, R. M., 1967. *Progress report on slow-acting fertilisers in nursery experiments in England and Wales*, 1966. Departmental paper INF/10/C13, Forestry Commission Research Station, Farnham, Surrey.

ANON., 1967. *Phosphatic fertilisers for farm crops*. Advisory Leaflet No. 442. Ministry of Agriculture, Fisheries and Food, London.

ANON, 1970 Soil Structure and Subsoiling. *Ministry of Agriculture, Fisheries and Food, Short-term Leaflet*. 114.

BENZIAN, B., 1966 Manuring young conifers: Experiments in some English nurseries. *Proceedings of the Fertiliser Society* **94**, 5–37

BENZIAN, B, 1966 Risk of damage from certain fertiliser salts to transplants of Norway spruce and the use of slow-release fertilisers. *Forestry (Supplement)*, 65–69.

BENZIAN, B., 1967 Test on three nitrogen fertilisers—'Nitro-chalk', formalised casein and isobutylidene diurea—applied to Sitka spruce (*Picea sitchensis*) seedlings in two English nurseries. *Colloquium on forest fertilisation. (Proceedings of Vth Colloquium of the International Potash Institute, Finland)*, pp. 171–175.

BENZIAN, B., and FREEMAN, S. C. R., 1967 Effect of "late-season" N and K top-dressings applied to conifer seedlings and transplants on nutrient concentrations in the whole plant and on growth after transplanting. *Report on Forest Research*, 1967, 135–140.

BENZIAN, B., BOLTON, J. and MATTINGLY, G. E. G., 1969 Soluble and slow-release PK fertilisers for seedlings and transplants of *Picea sitchensis*. *Plant and Soil*, **31**, 238-256.

BOLTON, J. and BENZIAN, B., 1970 Sulphur as a nutrient for Sitka spruce seedlings and radish grown on a sandy podzol in England. *Journal of Agricultural Science Cambridge* **74**, 501-504.

BOLTON, J. and COULTER, J. K., 1965 Distribution of fertiliser residues in forest nursery manuring experiment on a sandy podsol at Wareham, Dorset. *Report on Forest Research*, 1965, 90–92.

BRIND, JANET E., 1965 *Studies on the effect of partial sterilization on the soil micro-population*. Supplementary paper in Vol. I, Bulletin 37, Forestry Commission London 206-209.

FAULKNER, R., 1956 *Greencrops compared with hopwaste as heathland nursery treatments*. Research Branch Paper No. 19, Forestry Commission, London.

FAULKNER, R., 1960 Summary of recent research into nitrogen, phosphate and potash manuring of conifers in nursery seedbeds in Scotland and Northern England. *Report on Forest Research*, 1959, 126–140 and 141–160.

FAULKNER, R. and MACDONALD, A., 1954 *Inchnacardoch nursery long-term soil fertility trial*. Research Branch Paper No. 15, Forestry Commission, London.

GUILLEBAUD, W. H., 1937 Green manuring in forest nurseries. *Journal of the Forestry Commission*, **16**, 20–32.

HEWITT, R. J., 1966. Physiological approach to the study of tree nutrition. *Forestry (Supplement)*, 49–59.

LEVISOHN, I., 1965. Mycorrhizal Investigations (Supplementary paper in) Bulletin 37, *Experiments in Nutrition problems in forest nurseries*, Forestry Commission, London, 228–235.

MATTINGLEY, G. E. G., 1966. Residual value of cumulative dressings of superphosphate rock phosphate and basic slag on a sandy soil at Wareham, Dorset. *Report on Forest Research*, 1965, 93–96.

MATTINGLEY, G. E. G., 1970 Residual value of basic slag, Gafsa rock phosphate and superphosphate in a sandy podzol. *Journal of Agricultural Science, Cambridge* 75, 413-418.

RAYNER, M. C. and NEILSON-JONES, W., 1944. *Problems in tree nutrition*. London; Faber and Faber.

REDFERN, D. B., 1969. *The effect of organic soil amendments on damping-off*. (Personal communication).

REITH, J. W. S., 1963. The magnesium contents of soils and crops. *Journal of Science in Food and Agriculture*, **14**, 417–426.

SALTER, P. J. and HAWORTH, F., 1961. The Available Water Capacity of a Sandy Loam Soil. II. The Effects of Farmyard Manure and Different Primary Cultivations. *Journal of Soil Science*. **12(2)** 335–342.

VAARTAJA, O. 1965. *Biological control of seedling diseases in nursery soils*. Information report 0-x-3, Canadian Department of Forest and Rural Development.

WARREN, R. G. and BENZIAN, B., 1959. High levels of phosphorus and die-back in yellow lupins. *Nature*. London, **184**, p. 1588.

WILL, G. M., 1962 The uptake of nutrients from sterilised forest-nursery soils. *New Zealand Journal of Agricultural Research* 5, 425-432.

WILLIAMS, R. J. R. and COOKE, G. W., 1961. Some effects of farmyard manure and of grass residues on soil structure, *Soil Science*, **92**, 30-39.

## NOTES ON FURTHER READING

The first reference contains the experimental evidence on which most of present day manuring practice in British nurseries is based. The next two references are recent agricultural texts providing much information vital to a clear understanding of the processes influencing nutrient supply. The remaining references are to papers of some importance or interest. There are, in addition, reports of many important studies in the Forestry Commission annual *Report on Forest Research* for the years from 1950 to the present in chapters on "Nursery Investigations" in Parts I of the Report and in chapters on "Nutrition Experiments in Forest Nurseries" in Parts II of the Report. Many of these studies are also described in the *Annual Report of Rothamsted Agricultural Research Station*.

# Chapter 6
# SEED

The use of sound seed from stands of high inherent quality is widely recognised as the best means of ensuring fast-grown and healthy plantations capable of yielding good quality wood. Seed which is guaranteed to have been collected in seed orchards, or in selected and managed seed stands or seed production areas may be two or three times more expensive than seed collected from thinnings or from heavily coning trees of poor quality. The higher cost arises from the additional labour and supervision needed to get seed from good quality standing trees. Nevertheless, even these very much higher seed costs add only a very little to the cost of the newly established plantations, and these are more than covered if the plantations raised from selected seed grow only one per cent faster than plantations from unselected seed. Not only may this reasonably be expected, but also the incidence of gross defects of stem form and branching habit and susceptibility to disease or insect attack is likely to be reduced by using plants raised from selected seed.

## 6.1 Choice of Seed Origins

If home-grown seed is being sought, as a first principle, seed should be chosen from the very best stands in the locality where it is intended to plant. Very often, however, such seed will not be available and the second choice should be seed from the nearest registered seed source on a similar site. Failing a local registered source, advice as to other registered sources likely to be suitable should be obtained from the Forest Seed Association. See Section 6.7 for details. If only imported seed can be obtained, the following origins are to be preferred:

| *Species* | *Suggested Source* |
|---|---|
| Douglas fir | Washington coast and northern foothills of the west slope of the Cascade Mountains. |
| Grand fir | Vancouver Island, British Columbia, and low elevation in the foothills of the Cascade Mountains of Washington. |
| Noble fir | Coast Mountains or Cascade Mountains of Washington. |
| European larch | Carpathian Mountains, Sudeten Mountains. |
| Japanese larch | From natural forest in the Nagano prefecture, failing which, from the Hokkaido plantations. |
| Lodgepole pine | Coastal: Coastal Washington and Oregon. |
| Lodgepole pine | Inland: Southern Interior British Columbia, from between 2000 and 4000 ft in interior wet belt. |
| Scots pine | Not imported. |
| Corsican pine | Corsica. |
| Norway spruce | South-eastern Europe; otherwise German or Austrian Alps. |
| Sitka spruce | Queen Charlotte Islands, British Columbia; Coastal Washington (for lower elevation sites in Britain). |
| Western red cedar | Coastal Washington and Queen Charlotte Islands or Vancouver Island, British Columbia. |
| Western hemlock | Coastal Washington and Queen Charlotte Islands or Vancouver Island, British Columbia. |
| Beech | A good stand in France, Belgium, Holland, Denmark or Germany. (The quality of the stand is the most important factor). |

More detailed information is contained in Forestry Commission Bulletin No. 30, *Exotic Forest Trees in Great Britain* (HMSO, 1957). See also; Provenance and' the supply of forest tree seed, by R. Lines in *Quarterly Journal of Forestry*, **59** (1965), pages 7–15.

## 6.2 Purchase of Seed

Seed may be purchased either from seed merchants or from the Forestry Commission. Prospective purchasers from the Forestry Commission should write to the Seeds Officer, Forestry Commission Research Station, Alice Holt Lodge, Wrecclesham, Farnham, Surrey.

TABLE 17

FOREST TREE SEEDS OF THE FOLLOWING KINDS ARE INCLUDED IN THE SEEDS ACT, 1920

| English Name | Current Botanical Name | Minimum weight of sample for test under ISTA* rules | |
|---|---|---|---|
| CONIFEROUS SPECIES | | Ounces | Grams |
| Silver fir | *Abies alba* Mill. | 8 | 240 |
| Grand fir | *Abies grandis* Lindl. | 4 | 100 |
| Noble fir | *Abies procera* Rehd. | 6 | 160 |
| Lawson cypress | *Chamaecyparis lawsoniana* (A. Murray) Parl. | 1 | 25 |
| Monterey cypress | *Cupressus macrocarpa* Gord. | 1½ | 40 |
| European larch | *Larix decidua* Mill. | 1 | 25 |
| Japanese larch | *Larix kaempferi* Carr. | 1 | 25 |
| Hybrid larch | *Larix* × *eurolepis* Henry | 1 | 25 |
| Norway spruce | *Picea abies* (L.) Karst. | 1½ | 40 |
| Serbian spruce | *Picea omorika* Purkyne | 1 | 25 |
| Sitka spruce | *Picea sitchensis* (Bongard) Carr. | 1 | 25 |
| Lodgepole pine | *Pinus contorta* Loud. | 1 | 25 |
| Mountain pine | *Pinus mugo* Turra | 1½ | 40 |
| Austrian pine | *Pinus nigra* Arnold var. *nigra* Harrison | 3 | 80 |
| Corsican pine | *Pinus nigra* Arnold var. *maritima* (Ait.) Melville | 3 | 80 |
| Monterey pine | *Pinus radiata* D. Don. | 6 | 160 |
| Scots pine | *Pinus sylvestris* L. | 1½ | 40 |
| Douglas fir | *Pseudotsuga menziesii* (Mirb.) Franco | 2 | 50 |
| Wellingtonia | *Sequoiadendron giganteum* (Lindl.) Buch. | 1 | 25 |
| Redwood | *Sequoia sempervirens* (Lamb.) Endl. | 1 | 25 |
| Western hemlock | *Tsuga heterophylla* (Rafinesque) Sarg. | 1 | 25 |
| Western red cedar | *Thuja plicata* Lamb. | 1 | 25 |
| BROADLEAVED SPECIES | | Ounces | Grams |
| Norway maple | *Acer platanoides* L. | 30 | 900 |
| Sycamore | *Acer pseudoplatanus* L. | 14 | 400 |
| Common alder | *Alnus glutinosa* (L.) Gaert. | 1 | 25 |
| Grey alder | *Alnus incana* (L.) Moench. | ½ | 15 |
| Italian alder | *Alnus cordata* Desfont. | 1 | 25 |
| Birch, silver | *Betula pendula* Roth. | ½ | 15 |
| Birch, hairy | *Betula pubescens* Ehrh. | ½ | 15 |
| Sweet or Spanish chestnut | *Castanea sativa* Mill. | 300 seeds | |
| Beech | *Fagus sylvatica* L. | 32 | 1000 |
| Ash | *Fraxinus excelsior* L. | 14 | 400 |
| Red oak | *Quercus borealis* Michx. | 300 seeds | |
| Sessile oak | *Quercus petraea* (Matt.) Lieb. | 300 seeds | |
| Pedunculate oak | *Quercus robur* L. | 300 seeds | |
| English elm | *Ulmus procera* Salis. | 1½ | 40 |
| Wych elm | *Ulmus glabra* Huds. | 1½ | 40 |
| Smooth-leaved elm | *Ulmus carpinifolia* Gled. | 1½ | 40 |

*ISTA—International Seed Testing Association.

### 6.21 Regulations Governing the Purchase and Sale of Seed

The Seeds Act, 1920, and the Regulations made under the Act apply to seeds of the main conifer and hardwood species; (these are listed in Table 17 opposite). The quality of all such seeds sold or offered for sale must be declared; this declaration of quality must include:

(i) The seller's name and address.

(ii) A statement that the seed has been tested in accordance with the provisions of the Seeds Act, 1920.

(iii) Species.

(iv) Percentage purity.

(v) Percentage germination.

(vi) The country of origin, or if this is not known, a statement must be made to that effect.

The species for which a declaration of quality is required by the Seed Regulations, 1961, and the minimum weight of sample for analysis are listed in Table 17. (See also Section 6.9, page 52.)

## 6.3 Collection of Seed

Every effort should be made to collect most seed in good seed years because not only are cones and fruits plentiful but also the quality of the seed is then highest. When the seed crop is sparse, seed should not normally be collected even from seed sources of the highest quality because the cost of collection will be high and the germination capacity of the seed is often below average.

With Douglas fir and the Silver firs, the seed in poor seed years may be heavily infested with seed flies (*Megastigmus* spp.).

Good crops of seed can be expected at the intervals shown in Tables 18 and 19. When stock is to be raised annually from a particular seed origin, sufficient seed should be collected in years when crops are heavy to supply needs in lean years. Such seed will have to be brought to a suitable moisture content and kept in a refrigerated store. (See Section 6.6, Storage of Seed).

The methods of estimating cone and seed crops are described in Forest Record 39. *Collection of Cones from Standing Trees* (Seal *et. al.* 1965, HMSO).

### 6.31 Choice of Seed Sources when Collecting Seed in Great Britain

The majority of older stands of the more important species in Great Britain have been examined and classified according to their suitability as sources of seed. The classes used are "normal", "almost plus" or "plus". A normal stand is one in which between 25 and 50 per cent of the dominant trees are healthy and have straight stems and good well-shaped crowns. In "almost plus" and "plus" stands the proportion of good seed trees is 50 to 75 per cent and over 75 per cent respectively.

While seed collected from one or more trees in a good seed source can be expected to produce good progeny, seed collected from single *isolated* trees may not do so, even though the tree may be of good growth and form. Most, but not all, trees of economic importance normally require to be cross-pollinated for the production of normal seed; trees that are self-pollinated often fail to set seed properly, and a proportion of the seed which is set may germinate to produce malformed or slow growing in-bred plants.

### 6.32 Time of Collection

The times to collect seed are given in Tables 18 and 19. The germination percentage of seed collected too soon is lower than average and often does not store well. If collection is too much delayed, the seed will have fallen and will be lost; this applies especially to Western hemlock, Western red cedar, Lawson cypress and the Silver firs among conifers and elm among broadleaved trees.

The heavy-seeded hardwood species such as the oaks, beech and Sweet chestnut, first shed malformed and empty fruits, usually following the first autumn frost; this should be gathered up and discarded so that the sound fruit and seed which falls a week or so later can easily be distinguished.

It is most important to ensure good storage conditions for the first collected cones, fruits or seed while the remainder of a collection is completed. Bags full of seed or cones must be kept well ventilated; the bags must be porous and not impervious. **Polythene bags are unsuitable** for cones or seeds.

If possible, seed should not be collected in very wet weather because wet seed is more difficult to prepare for storage and may very rapidly go mouldy or heat up.

### 6.33 Methods of Collection

CONIFERS

When seed is to be collected from good conifer plantations, whether managed specifically as seed stands or not, the seed trees may have to be climbed and the cones picked by hand. A whole range of tree climbing and cone collection equipment is now available, including ladders for trees with up to 30 feet/*10 m* of clear stem, tree bicycles for trees with more than 30 feet/ *10 m* of clear stem, safety belts and ropes to permit safe movement in the crowns of the seed trees, and for some species, rope scrambling nets rigged over the crown. Methods of

TABLE 18

SEED PRODUCTION OF CONIFEROUS TREES IN BRITAIN

Compiled from Matthews, 1955, Seal, Matthews and Wheeler, 1963 and Forestry Commission Records

| (1) English Name | (2) Age of First Good Seed Crop (years) | (3) Age of Maximum Production (years) | (4) Average Interval between Good Seed Crops | (5) Recommended Time of Seed Collection | (6) | (7) | (8) Notes | (9) Notes on Seed Collection | (10) Average No. of Cones per bushel/*hectolitre* | (11) Yield in Ounces of Clean Seed per bushel of cones/*grams per litre* | (12) | (13) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Earliest | Normal | Latest | | | | Lowest | Average | Highest |
| Scots Pine | 15–20 | 60–100 | 2–3 | Nov. | Jan. | Feb. | Some seed borne every year | Some seed retained in cones until early spring | 2 000/*5500* | 6/*5* | 8/*6* | 10/*8* |
| Corsican Pine | 25–30 | 60–90 | 3–5 | Dec. | Jan. | Feb. | Most seed produced in SE & E England | Good crops occur less frequently in Scotland | 1 000/*2800* | 6/*5* | 11/*9* | 16/*13* |
| Lodgepole Pine | 15–20 | 30–40 | 2–3 | Sept/ Oct. | Oct/ Nov. | Nov. | | Collect before Scots and Corsican pine | 1 600/*4500* | 2/*2* | 5/*4* | 9/*7* |
| Mountain Pine | 15–20 | 30–40 | 2–3 | Nov. | Jan. | — | A good seed producer | | — | — | — | — |
| European larch | 15–20 | 40–60 | 3–5 | Nov. | Dec. | Jan. | Flowers often damaged by frost | As for Scots pine | 3 600/*10000* | 9/*7* | 13/*10* | 36/*29* |
| Japanese larch | 15–20 | 40–60 | 3–5 | Sept. | Sept. | Oct. | Flowers often damaged by frost | Also during November in Scotland in some years. Collect before European | 3 500/*9500* | 12/*10* | 17/*14* | 20/*16* |
| Hybrid larch | 15–20 | 40 | 3–5 | Sept. | Sept. | Oct. | Flowers often damaged by frost | | 3 100/*8500* | 5/*4* | 14/*11* | 16/*13* |
| Douglas fir | 30–35 | 50–60 | 4–6 | Sept. | Sept. | Oct. | | Collect when cones a light golden brown or yellow colour | 1 100/*3000* | 3/*2* | 6/*5* | 8/*6* |
| Norway spruce | 30–35 | 50–60 | | Oct. | Oct. | Nov. | Rarely seeds heavily | As for Scots pine | 350/*1000* | 9/*7* | 16/*13* | 19/*15* |
| Sitka spruce | 30–35 | Begins at 40–50 | 3–5 | Sept. | Sept. | Oct. | | | 1 300/*3600* | 6/*5* | 11/*9* | 16/*13* |
| Serbian spruce | 20–25 | 40 | 2–4 | Oct. | Nov. | Dec. | Shows promise of being a good seed producer | Also during December in Scotland in some years | 2 300/*6000* | — | 9/*7* | — |

TABLE 18—*continued*

| (1) English Name | (2) Age of First Good Seed Crop (years) | (3) Age of Maximum Production (years) | (4) Average Interval between Good Seed Crops | (5) Recommended Time of Seed Collection | (6) | (7) | (8) Notes | (9) Notes on Seed Collection | (10) Average No. of cones per bushel/*hectolitre* | (11) Yield in Ounces of Clean Seed per bushel of cones/*grams per litre* | (12) | (13) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Earliest | Normal | Latest | | | | Lowest | Average | Highest |
| Common Silver fir | — | 40–60 | — | Aug. | Aug./Sept. | — | A poor seed producer so far | Collect immediately the scales loosen and the cone softens, otherwise seed will be lost | — | — | — | — |
| Grand fir | 40–45 | — | 3–5 | Aug. | Aug./Sept. | Sept. | | | 250/*700* | — | 32/*26* | — |
| Noble fir | 30–35 | 40–60 | 2–4 | Aug. | Aug./Sept. | Sept. | | | 80/*2200* | 22/*18* | 27/*22* | 46/*37* |
| Western hemlock | 30–35 | 40–60 | 3 | Aug. | Sept. | Sept. | | Collect as soon as cones change colour from bright green to yellow and the tips of the seed wings are visible and a light brown colour | 21 000/*58000* | 9/*7* | 16/*13* | 29/*23* |
| Western red cedar | 20–25 | 40–60 | 2–3 | Aug. | Sept. | Sept. | A good seed producer | | 71 000/*190000* | 15/*12* | 17/*14* | 22/*18* |
| Lawson cypress | 20–25 | 40–60 | 2–3 | Aug. | Sept. | Sept. | A good seed producer | | 38 000/*107000* | 32/*26* | 55/*44* | 79/*63* |

*Notes.* Column 4 — The figures refer to the intervals between good seed years. In Scots pine for example 2–3 years of relatively poor production will generally follow a good seed year.

Columns 5, 6 & 7. Sept./Oct. means at the end of September or beginning of October. A dash means no data is available.

Column 10. 1 bushel = 8 gallons = 36.48 litres.

TABLE 19
SEED PRODUCTION OF BROADLEAVED TREES IN BRITAIN

| English Name | Age of First Good Seed Crop (years) | Age of Maximum Production (years) | Interval between Good Seed Crops | Recommended Time of Seed Collection | | | Notes (For all species, see also Table 22) |
|---|---|---|---|---|---|---|---|
| | | | | Earliest | Normal | Latest | |
| Common alder | 15–20 | 30 | 2–3 | Sept. | Oct. | Nov. | |
| Ash | 25–30 | 40–60 | 3–5 | Aug.(1) | Oct.(2) | Nov. | (1) For immediate sowing (2) For stratification for 16–18 months |
| Beech | 50–60 | 80–200 | 5–10 | Sept. | Oct. | Nov. | Flowers sometimes damaged by late frosts |
| Birch | 15 | 20–30 | 1–2 | Aug. | Aug./ Sept. | Sept. | Good seed producers in Britain. Some seed most years |
| Broom | 3 | 5–7 | 1 | | Aug. | | Pick pods when black and spread thinly on tarpaulin in bright sun to get pods to open |
| Horse chestnut | 20 | 30 | 1–2 | Sept. | Oct. | Nov. | |
| Sweet chestnut | 30–40 | 50 | 1–4 | May | June | June | A warm late summer is required to ripen nuts. Collect biggest nuts only. |
| Wych elm | 30–40 | 40 | 1–2 | May | June | June | Pick when green pigment has disappeared from the seed wing. |
| Gean (Wild) Cherry, Bird cherry | 20(?) | 30(?) | 1–3 | | Sept. | Oct. | |
| Hawthorn | 10 | 15 | 1–2 | Sept. | Oct. | Nov. | Stratify 18 months |
| Holly | 20 | 40 | 2–4 | Nov. | Dec. | Jan. | Stratify 16 months |
| Hornbeam | 30 | 40–80 | 2–4 | Aug. | Sept. | Nov. | Stratify 18 months |
| Small leaved lime | 20–30 | — | 2–3 | — | Oct. | — | Stratify 18 months |
| Large leaved lime | 20–30 | — | 2–3 | — | Oct. | — | Stratify 18 months |
| Maple—*see* Sycamore below | | | | | | | |
| Pedunculate Oak | 40–50 | 80–120 | 2–4 | Sept. | Oct. | Nov. | A good mast producer. Some acorns most years |
| Sessile oak | 40–50 | 80-200 | 3–5 | Sept. | Oct. | Nov. | |
| Red oak | 30–40 | — | 2–4 | Sept. | Oct. | — | |
| Rowan | 10 | 15 | 1–2 | July | Aug. | Sept. | |
| Spindle | 15 | 30 | 2–4 | Sept. | Oct. | Nov. | |
| Sycamore, Norway maple and Field maple | 25–30 | 40–60 | 2–3 | Sept. | Sept./ Oct. | Oct. | Some seed most years. Field maple needs 18 months stratification |

collection and the required equipment are fully described in Forest Record 39. Collection from standing trees is perfectly safe when tackled with the right equipment and with due attention to safety.

On most larger estates, two or three forest workers under a supervisor can usually be found who are willing to be trained in these methods.

Recent trials of a tractor-mounted "tree shaker" have caused too much damage to the test trees, whilst bringing down cones, for the technique to be accepted.

Where extensive areas of mature good quality "normal" stands exist, it may be possible to clear-fell enough seed-bearing trees in a good cone year. Workers at ground level can then pick large quantities of cones. This has recently been shown an economical means of collecting Sitka spruce seed in Scotland and Wales. Such collections are justifiable *only* when the stands are of good form and vigour, and, in addition, the original seed provenance can be inferred with reasonable certainty, and is reliable, At present, collection from felled trees is restricted mainly to Sitka spruce.

BROADLEAVED TREES

The method of collection of fruits and seeds of broadleaved trees varies with species.

*Oak, beech, Sweet chestnut* (Forestry Commission Leaflet No. 28). Acorns, beechnuts and chestnuts are picked from the ground below the seed trees. Hand picking may be cheap and effective if school children or casual labour can be induced to collect sound seed from under good seed trees; in this way, much defective seed is avoided and no further cleaning is required. However, it is of the very greatest importance to ensure that the seed trees are of good quality. Seed should be taken from such collectors daily lest it deteriorate under bad storage conditions. Polythene bags are not suitable containers for newly collected seed, which if left in them for much more than a day, starts to heat up and to sweat and blacken. Open-woven hessian sacks that permit the free movement of air are suitable. If large quantities of seed are required, the ground under selected trees should be swept, or hessian or tarpaulins spread out as soon as possible after the first empty and unsound seed has come down. The sound seed can then be quickly swept or raked up off the prepared forest floor, or gathered from the tarpaulins.

*Rowan, holly and hawthorn.* Berries of these species should be picked when fully ripe. Generally, sufficient fruit can be gathered from the lower crown to make unnecessary the use of long ladders and climbing ropes.

*Birch* catkins and "cones" of *alder* must be picked in September or October shortly before the catkins break up or the "cones" open to shed the seed.

*Elm* seeds should be swept from the ground as soon as possible after the seed has fallen, or it may be picked from the tree between mid-May and early June when the green pigment in the seed wing has disappeared and the seed is fully developed.

*Ash and sycamore* (Forestry Commission Leaflet No. 33). Seed of these species is nearly always gathered direct from the seed trees in late September or October. Collection of seed from the ground is sometimes practicable where there has been a heavy fall, but this method is usually slow and expensive, and unlikely to provide seed of good quality. Little seed is borne within easy reach of the ground, but it is often possible to bend down fruit-bearing branches with a pole and hook, or long-armed pruners may be used to cut off the extremities of fruit-bearing branches. To collect seed from higher up the tree it will be necessary to climb, using the safety-belt and safety line etc as described in Forest Record No. 39.

Seed of *False acacia* has to be collected from trees in the same way as for ash and sycamore.

## 6.4 Seed Extraction

### 6.41 Conifers

The ease of extracting seed from the cones varies with species. For some, such as the Silver firs, no special steps are required because the cones break up soon after collection; at the other extreme, the cones of pines and larches may have to be dried and tumbled in drums for several hours to free the seed.

The conditions essential for successful extraction are:

(a) Protection of cones from rain.

(b) Continuous free access of air to all cones (except for the time while they are in transit from the forest to the seed extractory).

(c) Exclusion of rodents and birds.

(d) As prompt extraction of seed as the condition of the cones will permit.

After collection, cones may need to be stored in sacks while awaiting extraction. Such sacks must be stored in very well ventilated sheds where they are protected from the rain. Sacks must be arranged on shelves or struts so that there is free circulation of air on all sides. Sacks full of wet cones must not be stored in a heap otherwise those in the centre of the heap will deteriorate rapidly.

When seed is to be extracted, cones may be spread out in shallow boxes or trays in a cool well-ventilated shed or store. For some species, such as Western hemlock, Western red cedar and Lawson cypress, this may be sufficient to open the cones. Pine, spruce and larch cones are normally dried in a kiln until the scales have separated fully. Various patterns of kiln are available but the principle underlying each is the provision of a regulated flow of warm dry air so that all the cones dry uniformly and as quickly as possible without risk either of over-heating or of so "case hardening" the cones that the outermost parts become too dry to allow normal movement of the scales.

In the most modern kilns, the temperature of the air-stream is raised progressively as drying proceeds; there is forced-draught air-circulation and seeds are speedily removed from the source of heat as soon as they are freed from the cone. The temperature employed depends on moisture content of cones. The safe temperature for all cones is about 30°C (90°F), rising to 60°C (140°F) when the moisture content of cones is below 10 per cent.

If no special equipment is available and only a few cones have been collected, they may be placed on a warm radiator or on a sunny window sill. Cones should never be left to open where it is too hot to rest the hand comfortably.

After drying the cones, seeds have to be separated. This may be done by shaking the cones in coarse sieves or rotating them in a wire mesh drum. The freed seeds will then fall through the mesh onto a tray or other convenient container. The time required for shaking or turning depends on the species and the condition of the particular lot of cones being handled. European larch and Norway spruce seed may be held tightly in the cone and long periods in a drum are sometimes required even to the extent of allowing the cone scales to wear off by rubbing one against the other before the seeds fall free.

Cones of European larch have in the past been crushed between rotating rollers fitted with heavy steel spikes. This procedure is not completely satisfactory since there is inevitably some damage to the seeds.

Those seeds where the seed wing is detachable must then be dewinged by gentle rolling around between cloth sheets or by passing through a specially designed dewinging machine.

Wings, cone scales and other impurities must then be separated from the seed by winnowing, after which the seed is then ready for testing for moisture content and for storage.

### 6.42 Hardwood Seed

Hardwood fruit and seeds vary immensely in size and shape, ranging from those in husks, e.g. chestnut and beech, those such as holly and rowan in berries, and yet others which are dry, with or without wings. In general, seed should be separated from its husk if dry, or from its soft pulp if a berry.

Hardwood seed like birch with small wings, has to be sown with the wing remaining on the seed coat, while seed like sycamore is best sown with the wing broken off.

Pulpy fruits should be macerated by squashing or gentle mashing, mixed with water. The pulp and skins etc can usually be separated from the seed by washing through appropriate sieves or by differential flotation in a deep bowl through which a slow stream of water is flowing.

## 6.5 Seed Testing

Tests for the purpose of a declaration of quality under the 1920 Seeds Act must be made either at one of the Official Seed Testing Stations, or at a Private Seed Testing Station licensed by the Ministry of Agriculture, Fisheries and Food. Licences for private seed-testing stations are granted to enable the licensee to test his own seed which he intends to sell. In addition, a private station may test seed for any nurseryman or grower who declares that the results of the test will not be used in connection with a declaration for sale.

The Forestry Commission has a licensed Private Seed Testing Station and for a small fee will perform tests required for any nurseryman who declares that the seed to be tested is for his own use and not for sale. Applications should be made to the Private Seed Testing Station, Forestry Commission Research Station, Alice Holt Lodge, Farnham, Surrey.

The statutory seed year runs from 1 August to 31 July. Seed sold, delivered or offered for sale during this period must have been tested during the same period, except that the analysis particulars of seed sold and delivered, or offered for sale during August and September may be based on tests made after August of the previous year. (See Section 7.32, page 67, for 'Cut-test'.)

### 6.51 Selection of the Sample for Testing

When seed is tested, the sample on which the test is made has to be representative of the whole. No matter how accurate the technical work in the testing laboratory, the results can only show the quality of the sample submitted for analysis. Therefore, every effort must be made to ensure that the submitted sample accurately reflects the composition of the whole seed lot. The following procedure is that approved by the International Seed Testing Association.

Prior to sampling, a bulk should be well mixed so as to be as uniform among its parts as is practicable.

When the bulk is in sacks or other containers, the number of sacks or containers to be sampled must be in accordance with the following table.

| *Number of sacks or other containers in the bulk* | *Number of sacks or other containers to be sampled* |
|---|---|
| 1 to 5 (inclusive) | Each sack or other container. |
| 6 to 30 (inclusive) | 1 sack or other container in 3, selected at random, but in any case not less than 5. |
| Over 30 | 1 sack or other container in 5, selected at random, but in any case not less than 10. |

When practicable, seed in sacks or other containers should be sampled with metal spear ("walking-stick sampler") and in all cases portions of seed shall be taken from the seed on the top, middle and bottom of each selected sack or container. Seed stored in undivided bulk must be sampled from at least ten representative locations.

When the individual portions taken from the bulk together exceed the amount required (Table 17), they shall be put together and well mixed. This accumulated sample shall be reduced by employing the "halving method", i.e. by dividing the aggregate sample into two equal parts, rejecting one of such parts and after re-mixing the other part, dividing it into equal parts and rejecting one of them and so on until the amount required is attained.

Samples for purity and germination analysis should be sent in standard envelopes obtainable from the Seed Testing Station. The envelopes *must* be packed inside a protective cover or carton to prevent damage to the seed during transit. Samples for *moisture content* tests should be sent in moisture-proof rigid containers. *No other samples* should be submitted in moisture-proof containers.

Each sample should have the particulars as follows:

(1) Full name and postal address of sender.

(2) Date of sampling.

(3) Kind and variety of the seed.

(4) Test required.

### 6.52 Characteristics to be Tested

Seed may be tested for a great variety of characteristics, the most important being: purity, seed size, germination, moisture content and seed health.

The essence of good seed testing is the application of reliable standard methods of examination to ensure that uniform and reproducible results are obtained. An important advance in the standardisation of test methods was the adoption of International Seed Testing Rules for Forest Seed. All forest seed testing in this country is carried out in accordance with the conditions laid down in the International Seed Testing Association (I.S.T.A.) Rules.

### 6.53 Purity

The object of purity analysis is to determine the percentage by weight of three components, pure seed, other crop seed and inert matter.

Since the germination test is based on pure seed, it can be readily seen that the purity analysis and germination test are complementary to each other. The production potential of a seed lot can be determined only when the purity analysis and the germination tests are considered together.

### 6.54 Germination

The main aim of this laboratory test is to estimate the maximum number of seeds which can germinate in optimum conditions.

The sample selected for this, the most important of the seed tests, is taken following a standardized laboratory procedure, ensuring unbiassed selection of seed. (Section 6.51).

This sample is then either placed in germination tanks (Plate 2) under closely regulated conditions of moisture, temperature, aeration and light, or if dormant to any extent, may be either first "pre-chilled" or subjected to an "excised embryo test" or "Tetrazolium test" as described below. Some lots may have both dormant and non-dormant seed and in such cases, two germination tests are required in order to determine the extent of dormancy.

#### "STANDARD" COPENHAGEN TANK TEST

(See Plate 2 in central inset).

In this test, the selected seeds are placed over a Copenhagen or Jacobsen Tank where they are allowed to germinate on moist filter paper. The temperature is controlled by thermostat. Normally, one test consists of 400 seeds counted at random into replicates of 100, 50 or 25 seeds. Large seeds like acorns, chestnuts, etc are tested in sand dishes kept in incubators.

#### EXCISED EMBRYO TEST

When severe dormancy is encountered and several months of pre-treatment are required, a quick answer may be obtained by the "excised embryo test". In this, the embryo is removed from the endosperm and placed on filter paper in a Copenhagen tank; germination is indicated by the embryo remaining firm and fresh; the test is concluded within 21 days.

TETRAZOLIUM TEST

Still more rapid is the "tetrazolium" test. In this test, excised embryos are soaked in solution of a colourless chemical, tetrazolium bromide. Where this compound comes into contact with living cells, it is reduced to an insoluble red dye which stains the live tissues causing the reduction. The stained embryos are classified according to the extent of the staining and such test can be concluded in hours instead of the months required for germination of dormant species. The "tetrazolium" test is now officially approved for a number of species with dormant seed, like lime, ash and beech.

GERMINATION CAPACITY

The germination quality of a seed lot can be described in a number of ways; the most common expression is *germination capacity* which indicates the total percentage of seeds which have germinated when the test was terminated plus remaining sound ungerminated seeds. These are usually expressed separately, thus 87 per cent + 6 per cent. No germination test is considered complete until all seeds remaining ungerminated have been cut and classified into sound (or viable by a tetrazolium test), rotten and empty seeds.

GERMINATION ENERGY

Another expression used sometimes is *germination energy* which indicates the percentage of seed that has germinated in a limited period, i.e. after 5, 7 or 10 days instead of 21 or more days as required for determination of germination capacity. In a wide sense, germination energy represents the percentage of quick germinating seeds.

In agriculture, germination energy may be used in a slightly different sense, "germination vigour" or some measure of rate of germination being used to describe the concept some foresters have intended to convey by "germination energy".

The interest in germination energy or germination rate is based on a theory that only those seeds which germinate rapidly and vigorously under the favourable conditions in a germinator are likely to be capable of producing seedlings in the field, where weak or delayed germination is often fatal.

At present, insufficient is known about germination energy to enable it to be used in forest nurseries.

DORMANCY

Seeds which have been extracted from mature cones or ripe fruit normally start to germinate immediately they are introduced into a warm, moist condition.

Seeds which do not respond to conditions favouring germination are said to be dormant. Dormancy may be caused in many different ways.

The embryo of the seed may not be fully developed when the cone or fruit is ripe. Such seeds require a period of after-ripening while the embryo grows to full size before germination can begin.

Dormancy may be induced by excessively hard or impermeable outer layers of the seed coat so that germination is delayed until these have to some extent decayed and softened so that water is able to enter the seed and germination can commence.

Dormancy may also be due to chemical inhibitors in the seed coat or in the endosperm, germination taking place only after the inhibitors have been inactivated.

Dormancy can very occasionally also be induced in normal seed. This has occurred when seed, after sowing, has just started to germinate but has then dried as a consequence of a period of very dry weather. Germination may then be delayed by a period of several weeks or even until the following year.

With species like ash, lime or Weymouth pine, *Pinus strobus*, all fully-ripened seeds are dormant. Seed of other species, like Austrian pine, *Pinus nigra*, is not normally dormant, however, some seed lots of such species may contain a proportion of dormant seed. If more than five per cent of the seed in any seed lot is dormant, it is worth while pre-treating that seed so that all seeds germinate quickly when the seed is sown. See tables 21 and 22. Reports on germination tests in the seed laboratory may include a guide to the proportion of dormant seed present.

### 6.55 Moisture Content

Seed moisture content determination is often important, particularly if seed is to be stored for long periods. The test is carried out using standard air-drying ovens where the seeds are dried at a constant temperature of 105°C. The moisture content is calculated on a basis of fresh seed weight.

### 6.56 Health

The seed health test is carried out by a pathologist in order to find out what proportion of the seed is contaminated with fungi. Health certificates are issued on request. See also Section 11.21, page 109.

### 6.57 Seed Size

The seed of many of the common forest species vary in size quite widely. Some variation is due to the location of the seed source—some species in more northerly plantations especially, yielding smaller seed than those in the south. Some variation is due to the weather in the season during the ripening of the seed. In warm seasons, seeds are usually larger than those ripening in cold seasons.

Seed size is expressed as the weight of 1000 pure seeds.

### 6.58 Viable Seeds per pound/kilogramme

For many years the standard practice in the Forestry Commission was to regulate sowing purely on the basis of germination capacity per cent, taking no account of the large variations in seed size. However, seed size is a major factor determining the number of seeds per pound/*kilogramme* which are able to germinate and all Forestry Commission seed test results have for some years now stated the number of viable seeds per pound/*kilogramme*, to take account of the variation in purity, seed size and germination per cent. The number of viable seeds per pound/*kilogramme* gives a valuable estimate of the potential seedling production per pound/*kilogramme* and serves as a starting point for calculation of seed requirements and sowing densities.

A recent innovation now widely used within the Forestry Commission is the concept of the "effective pound/*kilogramme*" of seed. This is defined as the weight of seed containing the number of viable seed in a pound/*kilogramme* of (average) quality. The "effective pound/*kilogramme*" has been found useful both in planning sowing programmes and calculating of seed prices. See Tables 23a and 23b, pages 63 and 64.

### 6.59 Interpreting Test Results

The nurseryman when given the test report is faced with the problem of interpreting the results in a manner which will provide a reasonable forecast of seedling yields. Actual germination and seedling survival in the field are affected by a complex of factors which are very difficult to forecast. In practice, the record of seedling yields obtained in past years from any given nursery provides the most useful basis for estimating future production from that locality. Records based on production on other soil types or in other climatic conditions are very little help in estimating production in a nursery where no records are available.

Records are best kept in terms either of the total yield of seedlings per "effective pound/*kilogramme*", or of the germination/survival factor. The latter is the ratio of seedlings surviving at the end of the year to the number of viable seeds sown.

## 6.6 Storage of Seed

### 6.61 Conifer Seed

Most species of conifer can be stored without loss of viability for several years, given proper control of the moisture content of the seed and the correct temperature of storage.

Seed usually needs to be dried to obtain the desired moisture content for long term storage. This is best achieved by passing a regulated stream of warm dry air through the seed until the moisture content is between 6 and 8 per cent, after which the seed is placed in air-tight containers. Pine, spruce and larch are best stored at between 2° and 5°C (36° and 41°F) and hemlock, red cedar and Douglas fir and *Abies* species at −5°C (23°F).

Seed collected by private owners may be stored for a fee at the Forestry Commission seed store, after any necessary correction of moisture content.

Seed newly extracted from cones may be stored until the following spring without further treatment if it is kept in closed jars or tins in a cool place such as a cellar. A clean metal dustbin with a close-fitting lid kept in a cool shed is a convenient means of storing seed for a few weeks.

### 6.62 Hardwood Seed

The small-seeded hardwood species can be stored for several years in the same way as most conifer seed. In contrast, oak, beech and other large seeded species can only be stored with certainty for one winter, though techniques are being developed which may in the future enable seed to be stored with certainty over two winters.

The most widely used method of storage for the large seeded species is described in detail in Forestry Commission Leaflets 28 and 33. (See *Further Reading* below). Soon after collection oak, beech and similar seed should be spread out in a cool, ventilated and vermin-proof store in a layer between 4 and 8 inches/*10 to 20 cm* deep; it should be regularly turned until the seed no longer sweats. If this is done, the lower layers of seed will not become blackened and mouldy. Beech needs turning daily in the fortnight after collection but oak needs turning only once or twice weekly. Turning should continue until the end of December. After this, until the time of sowing, as the seed continues to dry, it should be turned once a month and a little water sprinkled over it to keep it full and plump and to prevent wrinkling.

Acorns have also been stored successfully mixed in peat, or stored in small sacks standing separately on a well-ventilated platform. However, many nursery foresters prefer to sow their acorns soon after collecting them. Provided such seedbeds can be protected from depredations by mice and game birds, this successfully avoids the labour of storage.

A stratification pit for medium-sized hardwood seeds such as ash, maple and sycamore is shown in Figure 2, page 56.

Details of the preparation of seed for sowing are given in the next chapter.

### 6.7 Forest Tree Seed Association

There were at one time two Tree Seed Associations; the first was formed in Scotland in 1956 while the Tree Seed Association of England and Wales was formed in 1959. They amalgamated to form the Forest Seed Association in 1966. The object of the association is "to improve the quality of all species of forest trees by encouraging in all possible ways the use of seed and plants of the best known origins."

The Forest Seed Association does not trade in seed and plants. Its main business is to operate a certification scheme for seed collected from trees, woods and plantations registered as classified. Information and advice on choice of seed origin and matters connected with tree breeding and seed and plant production are also given where practicable.

Rules regulating the classification and registration of seed sources, extractories, seed stores, nurseries and poplar stool beds and lists of registered seed sources are published in the Members' Handbook.

Membership is open to all on payment of the annual subscription which is currently (1971) £3. No charge is made for registering members' seed sources, nurseries, etc.

Full details of membership can be obtained from the Secretary, Forest Seed Association, Alice Holt Lodge, Wrecclesham, Farnham, Surrey.

### 6.8 Identity Numbers

From its first purchases until the present, the Forestry Commission has maintained systematic records of the origin of the seed.

The description of seed sold by the Forestry Commission may include its Forestry Commission Identity Number. Especially for older seed lots, the records of origin have been on broad lines only; in other instances, the origin is recorded in detail. All available information on seed identity numbers in use until 1956 is given in Forestry Commission Research Branch Paper No. 29.

Since 1956, a system has been used which gives the year of purchase, a geographical code number based on the Universal Decimal Classification system and a suffix referring to particular localities or seed zones. Thus seed described as SS 69(7111)1 is Sitka spruce purchased in 1969 and originating from the Queen Charlotte Islands, British Columbia, from the neighbourhood of Massett. An outline of the U.D.C. system and a list of the more commonly used numbers, with maps, is given in Appendix IX, page 165.

### 6.9 Common Market and Seed Supplies

Entry by Britain into the European Economic Community (E.E.C.) will result in changes in some procedures affecting seed. However the details are not yet known (in early 1972).

The Section of this Chapter most likely to be affected is:—6.21, Regulations Governing the Purchase and Sale of Seed. Sections 6.7, Forest Tree Seed Associations, and 6.8, Identity Numbers, could also be affected. The changes are most likely to be concerned with certification of origin of seed, both that which is involved in international trade, and home collected seed.

#### Further Reading


Buszewicz, G., 1962. Longevity of beechnuts in relation to storage conditions. *Report on Forest Research*, 1961, 117–126.

Forestry Commission, 1957. *Exotic Forest Trees in Great Britain*. Bulletin No. 30. Forestry Commission, HMSO, London.

Forestry Commission, 1960. *Collection and storage of ash, maple and sycamore seed*. Leaflet No. 33, Forestry Commission, HMSO, London.

Forestry Commission, 1962. *Collection and storage of acorns and beech mast*. Leaflet No. 28, Forestry Commission, HMSO, London.

Forestry Commission, 1965. *Seed Identification Numbers*. Forestry Commission Research Branch Paper No. 29.

Holmes, G. D. and Buszewicz, G., 1956. Longevity of acorns with several storage methods. *Report on Forest Research*, 1955, 88–94. HMSO.

Holmes, G. D. and Buszewicz, G., 1958. *The storage of seed of temperate forest tree species*. Forestry Abstracts Leading Articles Series, No. 26. (Reprinted from *Forestry Abstracts*, **19**, pts. 3 and 4).

Hussey, N. M., 1954. *Megastigmus flies attacking conifer seed*. Leaflet No. 8, Forestry Commission, HMSO, London.

Maxwell, H. A. and Aldhous, J. R., 1967. Seed Collection in Northwest America. *Commonwealth Forestry Review*, 47, (127), 51–62.

Seal, D. T., Matthews, J. D. and Wheeler, R. T., (1965). *Collection of cones from standing trees*. Forest Record No. 39, Forestry Commission, HMSO, London.

# Chapter 7
# SEEDBEDS

The production of vigorous seedlings can be achieved cheaply in forest nurseries because of the high output per unit area. Given a suitable site and sustained good management over several years, high yields and low costs can regularly be achieved.

In this chapter, seedbed preparation, sowing and maintenance are considered in the sequence in which operations are normally undertaken. The nutrient requirements of seedlings are given in Chapter 4, page 21, while weed control methods are described in Chapter 10, page 92.

At the end of the chapter, there are sections on irrigation (7.5) and on special techniques for seedling production, i.e. "tubelings" (7.61), paper-pot seedlings (7.62) and Dunemann seedbeds (7.63).

## 7.1 Preparation of the Ground for Sowing

### 7.11 Cultivation of the Seedbed Area and Incorporation of Bulky Organic Manures

Where the seedbed area has been carrying a previous crop, the ground should be ploughed soon after clearance, to level it and bury any weeds present. Fallow land should also be ploughed in late autumn for the same reason. If ground is ploughed too early in the autumn, weeds will germinate and during mild spells in the winter will grow and spread.

Magnesian or ordinary limestone, ground mineral phosphate or any other material prescribed to correct a soil deficiency should be spread on fallow land as early in the winter or late autumn as possible.

Any bulky organic matter such as hopwaste, if required, should be spread evenly in late autumn or winter by agricultural dung-spreader, or by hand. Uneven distribution leads to uneven growth in the subsequent season. After spreading, hopwaste, etc should be ploughed or rotovated into the top 6 inches/15 *cm* of the soil. Any bulky organic material used must be weed and lime free.

### 7.12 Size of Seedbeds

Beds are normally 3 ft 6 in/*1.1 m* wide with alleys or paths between beds 1 ft 6 in/*0.5 m* wide. This bed width is just narrow enough to permit easy hand-weeding from either side. Beds are raised above the alleys; this defines them and provides drainage ways which minimise erosion of the sown area by storm water. Where the annual rainfall is no more than 40 inches/1000 *mm*, raising the beds 2 to 3 inches/*5 to 8 cm* is sufficient. With an annual rainfall over 40 inches/*1000 mm* beds need to be raised to 4 to 6 inches/*10 to 15 cm*.

### 7.13 Throwing up Seedbeds. (Plate 6).

The method will depend on the size of the nursery. Where the nursery area is in the region of 20 acres/*8 hectares* or more, mechanical equipment ought to be available to do most of the work. In smaller nurseries, some or all the work of preparation will have to be done by hand.

In larger nurseries, and especially where soils are light, beds should be thrown up using two potato-ridger ploughs set at a distance of 5 feet/*1.5 m* apart centre to centre. A wooden board or pair of metal bars should be fixed between the ridgers to level off the bed to an appropriate height (Plate 6). In this way beds are both thrown up and levelled in a single operation. Suitable ridgers can be made by removing the centre unit of any 3-unit agricultural potato ridger which fits the 3-point linkage of the nursery tractor. The additional bar, or bars, to level off the bed can usually be made locally and various forms are in use in different parts of the country. When using this implement, it is important that sufficient soil is moved from the edges of the bed to the middle, otherwise the subsequent rolling only consolidates the edges of the bed and leaves the middle loose.

In the smaller nurseries where beds have to be prepared by hand, the beds should be marked out 3½ feet/*1.1 m* wide with 1½ foot/*0.5 m* alleys between beds. Garden lines are run out to mark the edges of the beds, and soil is thrown from the alleys on to the beds by spade, each bed on either side of the alley receiving a spadeful alternately.

Beds may be thrown up at any time during winter or early spring while the soil is workable; the sooner they are prepared, the better. Where the soil is very sandy and does not require frost in order to obtain a tilth, beds may be rolled or raked level and should be left to pack down as hard as possible over the winter and early spring. However, where the soil is loamy or heavy, it is essential to fork up the surface of the newly made beds as roughly as possible to allow the soil to dry out and to ensure maximum exposure to frost, so that a good tilth is obtained.

### 7.14 Partial Soil Sterilization

In some long-established nurseries, the most pH-sensitive conifers may take two years to grow to a liftable size in spite of seed having been sown in good time. In such nurseries, seedlings may grow much bigger in the first season if the soil has been treated with formalin three or four weeks prior to sowing. Several other materials including steam, chloropicrin and chlorobromopropane have been used from time to time but none is currently used. See Appendix VI.

On responsive soils, formalin is effective but expensive. The combined cost of materials and application comes to between £160 and £200 per acre/*£400 to £500 per hectare*. Chloropicrin costs much the same as formalin, taking materials and application together, but has proved more hazardous to seedlings because of its persistence in nurseries with a high water table or where the soil has remained wet for considerable periods after treatment. Chloropicrin is a tear gas and is much more unpleasant to handle than formalin. Steam sterilization, though effective, is twice as expensive as formalin treatment. Recent trials have shown that dazomet can achieve as good a stimulus to growth as formalin and also controls weeds. See Section 7.63.

The best and most consistent results with formalin (and also chloropicrin and steam) have been obtained on sandy loam soils where the soil reaction is a little below pH 7. On other soils, varying results have been obtained. Before adopting the use of formalin on a large scale, it is therefore prudent to carry out a trial first on land similar to that on which the formalin might be used. If seedlings raised on formalin-treated soil in such trials are not consistently big enough to be transplanted at the end of the first growing season (provided of course that seed was not sown late), there is very little justification for the technique.

Formalin controls many diseases and weeds but the increases in the height following treatment are often greater than can be accounted for by the removal of pathogens and weed competition. Benzian (1965) discusses this in detail.

METHOD OF APPLYING FORMALIN

Formalin should be applied as a soil drench to prepared seedbeds at the rate of one gallon of horticultural grade formalin (containing 38–40 per cent formaldehyde) per 10 or 20 square yards/*6 litres per 10 or 20 sq m*. The higher rate seems necessary for best results in Scotland while the lower rate has been adequate in England and Wales. The quantity of water required to dilute the formalin is found by treating a small test plot to find the maximum quantity of liquid the bed will absorb without run-off into the alleys. Depending on the result of this test, one of the following rates of dilution should be selected.

It is essential for the beds to have been prepared and bulky organic materials incorporated before formalin is applied; after treatment, the soil should be disturbed as little as possible so as to minimise contamination from untreated soil.

The best time to apply formalin is between November and February. If left later, increases in height growth are smaller. On heavy soils, however, skilful planning ahead is required if seedbeds are to be prepared and ready for treatment at the best time.

| Volume of water saturating test plot to run-off | | Volume of water added to prescribed amount of formalin | |
|---|---|---|---|
| Per sq yd | Per sq metre | Per sq yd | Per sq metre |
| Over 2 gallons | *Over 10 litres* | 2 gallons | *10 litres* |
| 1½–2 gal. | *7.5–10 litres* | 1½ gallons | *7.5 litres* |
| 1–1½ gallon | *5–7.5 litres* | 1 gallon | *5 litres* |

Three weeks should elapse between treatment and sowing. There is no need to fork the soil before sowing.

Inorganic fertilizers should be applied at normal rates shortly before sowing. Nitrogen top-dressings should also be applied as for normal seedbeds.

### 7.15 Incorporation of Inorganic Fertilisers

For a full discussion of the quantities of fertiliser to apply see Chapter 4. Inorganic fertiliser is most conveniently applied in granular form, the rate depending on the content of plant nutrients of the particular brand selected and the requirements of the crop and the soil.

Granular fertiliser can be spread either by hand or by fertiliser distributor. It should be incorporated into the top-most two to four inches of the bed by light raking or rotovation before the bed is finally consolidated. Fertiliser has sometimes been pressed into the surface by roller at the time of final bed preparation, though this is a practice which in dry conditions can reduce germination somewhat because of the close proximity of seed and fertiliser. Faulkner (1960) showed that in several Scottish nurseries when muriate of potash and superphosphate were spread on the soil surface at the time of sowing and were not cultivated in, the rate of germination was slowed and the height growth at the end of season was slightly reduced. This and subsequent work also showed that there was no consistent benefit to be obtained by leaving the application of fertilisers to the last moment and that they could be applied any time in the nine weeks before sowing.

In studies of placement of fertiliser in drills in relation to band sown seed, drills of fertilisers containing potassic superphosphate substantially reduced the yield per pound of seed, although the seedlings that were obtained were appreciably larger than those from broadcast-sown beds in which the fertiliser was mixed evenly with the soil. Fewer losses occurred with placed phosphate than with potash.

### 7.16 Consolidation and Tilth. (Plate 7).

Beds must be well consolidated before sowing, in order that the soil moisture shall be able to reach the surface layers by capillary action and prevent drying out in warm dry weather to the detriment of newly germinated seed. This is especially important for coniferous and small seeded hardwood species. One effective and simple test is to press the surface of the bed firmly with the flattest part of the clenched fist. The consolidation is adequate when only a slight indentation can be made. It is scarcely possible to over-consolidate a soil when it is in a good working condition. If it is worked when too wet however, all the benefit of the previous winter's weathering can be lost by compression and aggregation of soil crumbs.

Beds which have to be consolidated soon after throwing up may be "trampled" with the feet, i.e. men tread evenly over the whole seedbed surface until it is uniformly firm, when the surface is raked *lightly* to remove footmarks. Alternatively, a roller weighing from 2 to 5 cwt/*100 to 250 kg* may be drawn once or more times over the bed according to the soil type after which no further raking is necessary. Suitable rollers may be made up locally from agricultural rollers. They should cover a single seedbed and be arranged to fit the 3-point linkage of the tractor. A specially manufactured hollow roller, the weight of which can be varied between 2½ to 7 cwt/*120 to 350 kg* by adjusting the amount of water inside, is also available.

On very sandy soils, beds thrown up early and consolidated naturally should be disturbed as little as possible before sowing. The natural consolidation following exposure to winter and early spring rain can scarcely be equalled by rolling beds which have been loosened or newly thrown up shortly before sowing. Particular care must be taken when incorporating inorganic fertilisers not to dig too deeply and lose the benefit of natural consolidation.

On loamy soils, a fine tilth has to be created in the top 2 to 3 inches/*5 to 8 cm* of soil immediately before consolidating. This may be achieved by working the soil with a rake or small rotary cultivator, or by a rotovator attached behind a tractor. On these soils, the interval between preparation of a fine tilth and consolidation of the soil must be kept to a minimum. If heavy rain intervenes after cultivation but before consolidation, the soil often loses its structure, becomes saturated with water and handles like porridge, and if dry weather follows may set hard. In these circumstances, the soil should be roughly forked up while moist and left to dry out again.

## 7.2 Preparation of Seed for Sowing

In the interval between receipt of seed in the nursery and treatment before sowing, seed must be kept cool, dry and protected from vermin. Clean metal dustbins have been found to be useful temporary containers for such seed. Alternatively, sacks or bags containing the seed may be suspended from the roof of a cool dry shed.

If seed is dormant, dormancy can be broken and seed made to germinate more evenly and quickly by a period of stratification or pre-chilling before sowing.

### 7.21 Stratification

Seeds of certain species can be made to germinate more quickly and regularly if, before sowing, they are subjected to a period of "stratification", i.e. storage mixed with sand in a pit exposed to the seasonal rainfall. (See also Forestry Commission Leaflet 33). Tables 21 and 22, page 59, include the more important species which respond to stratification and gives the recommended period of stratification or period of pre-chilling.

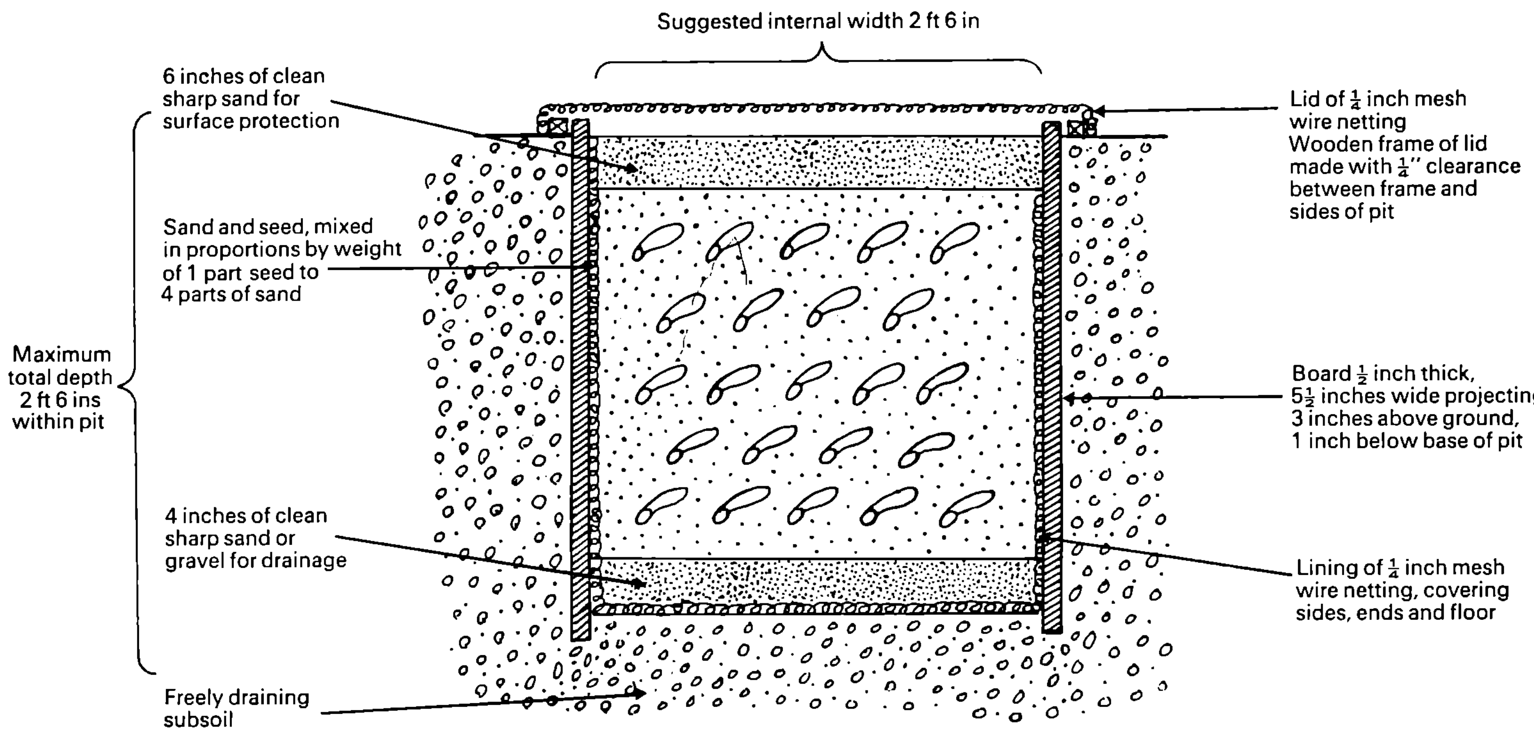
STRATIFICATION PIT - SITE

The site of the pit must not be liable to waterlogging, otherwise seed will rot. If the natural drainage is not perfect, tile or other drains must carry away from the bottom of the pit any water which otherwise would accumulate there. The pit should be in a cool, shady place so that germination is not hastened in the upper layers of the pit.

DIMENSIONS AND CONSTRUCTION. (See Fig. 2)

A much larger pit is required if hardwoods needing stratification are handled than if only conifer seed has to be stratified. For hardwoods, rectangular pits are probably the most convenient, and where up to two hundredweight/*100 kg* of seed is dealt with, a width of 2 to 2½ feet/*60 to 80 cm* is suitable.

The pit should first be dug out to a depth of from 2 to 2½ feet/*60 to 80 cm* and as long and wide as is necessary to hold all the seed that will be stratified at one time. Next, a fitting frame of wood treated with a preservative (but *not* creosote) should be made and the sides and bottom covered with ¼ inch mesh wire netting. ⅜ inch mesh netting is widely used but where mice are numerous and short of food, they may pass through ⅜ mesh wire netting. Mice also prefer to travel amongst herbage for protection, and are reluctant to pass over bare ground. The pit should therefore be sited on clean land. The top of the frame and netting sides should be arranged to protrude above ground to a height of about 2 inches/*5 cm*. A covering lid of wire netting on a frame should be made so that it fits snugly over the




VERTICAL SECTION THROUGH A STRATIFICATION PIT TO SHOW CONSTRUCTION

NOT TO SCALE

Metric equivalents of dimensions given are:—

| | | |
|---|---|---|
| $\frac{1}{4}$ inch = 0.6 cm | 3 inch = 7.5 cm | 6 inch = 15 cm |
| $\frac{1}{2}$ inch = 1.2 cm | 4 inch = 10 cm | 2 ft. 6 inch = 75 cm |
| 1 inch = 2.5 cm | $5\frac{1}{2}$ inch = 14 cm | |

Fig. 2. Stratification pit.

*Notes.* (1) All woodwork should be treated with a copper-based preservative. Creosote must not be used, as it may harm seeds close to the boards.

(2) Corner posts of the pit may be made of arris-sawn oak or angle iron driven well in. Boards must extend into the corner, those on the ends of the pit lapping the ends of the boards on the sides.

sides and is vermin-proof when in position, but nevertheless can be lifted off easily.

For conifer seed, the scale of the pit may be reduced, provided the same netting protection is given and the same depth of sand is allowed at the top of the pit.

FILLING THE PIT

The bottom 4 inches/*10 cm* of the pit should be filled with either sand or gravel for drainage. A known volume of seed is then mixed with roughly 4 times its weight of sand (i.e. sufficient sand so that each seed is separated) and placed in the pit to within 6 inches/*15 cm* of the surface. The weight of dry seed at the start must be recorded; this figure is needed subsequently to calculate the sowing density. The pit is then completely filled with sand to ground level, or above rather than below. Large lots of seed may be subdivided into quantities convenient to handle at the time of sowing. When relatively small lots of seed have to be stratified, the pit can be partitioned off with boards. With very small quantities, the mixed seed and sand can be placed in well drained, unglazed pots which are then submerged in the pit. The hole in the base of the pot must not be plugged, otherwise the seed will become waterlogged in the pot. Seeds may be prevented from falling through the hole by covering it with pieces of broken pot. During stratification the medium in the pit should always be moist and never excessively wet. There is no need to water the pit after filling.

TIMING OF STRATIFICATION

Seed should be placed in stratification so that the recommended period ends at a date when it is expected that sowing will be possible. Sometime before the expected time of sowing, the seed must be examined to see how far germination has progressed. In the South of England, hardwood seed should be first looked at no later than mid-February and conifer seed in early March. Further north, these dates should be delayed by one to three weeks.

Stratified seed should be sown when seeds are swollen and split and the tip of the radicle is visible but when the radicles of only a few seeds have begun to emerge. Once germination takes place in the pit, development is rapid and seed that has commenced to germinate cannot be retarded.

Stratified conifer seed which is sown when radicles have elongated will inevitably suffer serious mechanical damage during sowing. Also, hot dry weather in the period immediately after sowing may cause heavy losses. If germination is less advanced, such forms of damage are likely to be reduced.

Hardwood seed, in particular oak and sweet chestnut can sustain damage to or breakage of newly emerged radicles with far less ill-effect on yields.

### 7.22 Soaking of Seed

It has been the practice in some nurseries to soak seed for 24 hours or more prior to sowing. This practice appears to be of value only in nurseries where the soil is known never to dry out unduly, for example where there is a constant water table between one and two feet below the soil surface, or where beds can be irrigated. Elsewhere, if soaked seed is sown and a long period of dry weather follows, the yield of seedlings of seed may be much reduced.

### 7.23 Pre-chilling

Seed of Grand fir, Noble fir, and other species responsive to short-term stratification, has been found in trials to germinate as readily pre-chilled as stratified. The seed is put in a refrigerator or cold room at just above freezing point (about 2°C) for three to four weeks.

In the most recent trials seed has been soaked for twenty-four hours at 3 to 5 degrees Centigrade, and wet seed has been stored for three weeks at that temperature in a closed polythene bag, kept in a refrigerator, sometimes with and sometimes without, damp sand.

In earlier but also successful trials, seed was kept in porous sacks in a coldroom and was wetted daily with ice-cold water.

### 7.24 Seed dressings

While experiments show that various seed dressings and soaking have each occasionally depressed germination, it has for some time been customary to coat seed with red lead before sowing. This practice can be traced back to the latter part of the 19th century when it was introduced as a means of protecting seed from mice and birds. It is now considered to be valueless in this role. Colouring the seed makes it clearly visible against the soil and so eases the task of sowing evenly, and to this extent red-leading the seed remains justified. However other colouring materials may be equally suitable for this purpose.

Seed is dressed with red lead as follows: the seed is put in a piece of muslin or similar cloth and held in a bucket of water just long enough to wet all the seed. The seed should then be taken out and spread thinly on a flat surface to dry until it is just damp, when it should be mixed with the red lead. If it is too wet when mixed, the seed sticks together and is difficult to handle. If the seed and red lead are mixed together inside a polythene bag, the job is much cleaner and the progress of mixing can be seen through the bag.

There are many other forms of seed-dressing. Two used in forest nurseries in the United States and elsewhere are based on thiram or anthroquinone, sometimes mixed with other fungicides, insecticides or repellents. Thiram is primarily a fungicide and is used extensively in this role in other crops, though it is also used at much higher rates as a bird repellent. For details see Section 11.52. A thiram seed-dressing in some circumstances reduces early damping-off losses and in some years increases yields of seedlings by 5 to 10 per cent. Seed may be dressed with thiram by shaking the dry seed with a proprietary seed dressing containing 50 per cent thiram at the rate of 1 per cent of seed dressing per unit weight of seed. Thiram can irritate the nose, eyes or skin and should be handled with care.

Seed-dressings based on anthroquinone have shown no particular merit in trials in Britain.

Trials with other dyes to colour seed have shown that lithofar red A.S. dye + talc on seed coated very lightly with oil enables seed to stand out clearly on most soils. This dye + oil treatment has been found to be less damaging than red lead in its effect on subsequent germination, probably because of eliminating the operation of wetting and re-drying the seed when coating with red lead. Moistening and re-drying of seed for whatever reason reduces the germination capacity of seed.

The procedure for coating seed with lithofar red is first to prepare a mixture of 1 part of dye to 19 parts of French chalk. This mixture does not deteriorate in storage. The seed is then mixed with a small volume of linseed oil, stirring gently until all the seed appears evenly covered. Table 20 gives the amount of oil and the talc/dye mixture recommended for different species.

The freshly oiled seed should be mixed without delay with the talc/dye in a closed container until evenly coloured. The seed is then ready for sowing.

Dressed seed may be stored safely for several weeks; seed can therefore be dressed in a slack period in late winter rather than in the rush of work that often immediately precedes sowing.

It will be seen from Table 20 that the smaller seeds having a larger surface area per lb of seed require more material. The cost of materials for Scots pine or Norway spruce is approximately 1½p per lb/*4p per kg* of seed.

Dressings are not necessary for large seeded species such as the true firs and others like Western red cedar which are easily seen on most soils because of their natural colour.

Lithofar red A.S. dye can be obtained from Messrs Skilbeck, Dyestuffs and Chemicals, 55–57 Glengall Road, London, S.E.20.

TABLE 20

LITHOFAR RED A.S. DYE AS A SEED COLOURANT

| Species | Linseed Oil | | Talc/Dye* Mixture | |
|---|---|---|---|---|
| | ml per lb of seed | *ml per kg of seed* | g per lb of seed | *g per kg of seed* |
| Douglas fir<br>Corsican pine | 1.4 | *3.1* | 9.1 | *20* |
| Hybrid larch<br>Japanese larch<br>Scots pine<br>Norway spruce | 2.1 | *4.6* | 18.2 | *40* |
| European larch | 2.5 | *5.5* | 22.7 | *50* |
| Lodgepole pine | 3.0 | *6.6* | 27.2 | *60* |
| Sitka spruce<br>Western hemlock | 3.5 | *7.7* | 31.8 | *70* |

*Talc/Dye mixture, 19/1 by weight.

## 7.3 Sowing

### 7.31 Date of Sowing

The correct timing of sowing is probably the most important part of seedbed technique. If seed is sown too early, germination is slow and though the seedlings may grow well and be of good size by the end of the season, the yield is low. If sown too late, germination is inconsistent. In wet springs high yields of very small seedlings are obtained; in dry springs yields are low as many seedlings die due to drought, even though beds are shaded. Slow germinating species sown late germinate sporadically over a long period. Seed sown at the recommended time will in most years give a high yield of usable seedlings, without recourse to irrigation or shading.

The temptation to leave sowing until lifting for planting and lining out has been completed, must be resisted, unless it is the policy to produce two-year old seedlings, and a regular high germination of late-sown seed can be guaranteed. Lining out and planting programmes will scarcely be affected by the delay while seedbeds are sown, but if sowings are left late, it will often make the difference between seedlings that can be lifted after one year and those that have to go on for two years.

TABLE 21a

TREATMENT OF CONIFER SEED AND TIME OF SOWING: MAIN SPECIES

In sequence of sowing dates.

| Species | Sowing Period (Dry Seed) for England and Wales. For Scotland add 1–3 weeks | Period of Stratification** | Sowing Period (Stratified Seed) |
|---|---|---|---|
| Firs, *Abies* species | January/February | 6–(8) weeks | Late March |
| Douglas fir | Late February–Mid-March | 3–(6) weeks | Late March |
| Western hemlock,* Western red cedar,* Lawson cypress* | Late February–Mid March | Not normally required | |
| Lodgepole pine | Late February–Mid March | 3 weeks (But little real need for stratification) | Late March |
| Spruces | Mid–Late March | Not required unless dormant when seed should be stratified for 3 weeks | |
| Larches | Mid March–Early April | As for spruces | |
| Scots pine, Corsican pine | Late March–Early April | Not required | |

*Notes:* *Some claims are made for autumn sowing in the drier parts of England especially for these small-seeded species, but though big seedlings are raised, the yields are very often appreciably reduced.

**The corresponding period of pre-chilling is not known with certainty for all species. It may be rather less than the period of stratification.

TABLE 21b

TREATMENT OF CONIFER SEED AND TIME OF SOWING: EXCEPTIONAL SPECIES

| Species | Treatment before sowing | Notes |
|---|---|---|
| Maidenhair tree, *Ginkgo biloba* | Store at 2°C in airtight container to prevent drying out before sowing. | 400 seeds per lb/880 *seeds per kg*. Sow at 2 sq yd per lb/4 *sq m per kg*. Protect seedlings against early autumn frost. |
| Monkey puzzle tree, *Araucaria araucana* | Collect from ground in August/September. Store as for Maidenhair or store at 2°C in moist peat. | 125 seeds per lb/275 *seeds per kg*. Sow at 2 sq yd per lb/4 *sq m per kg*. Ease back into the soil any seed that pushes itself out while germinating. |
| Yew, *Taxus baccata* | Collect from tree in November. Crush fleshy aril and wash away from seed. Stratify seed for 16 months | 2000 seeds per lb/4400 *seeds per kg*. Sow at 8 sq yd per lb/16 *sq m per kg*. |

TABLE 22

TREATMENT OF SEED OF BROADLEAVED SPECIES AND TIME OF SOWING

(See also footnote page 62.)

| Species | Treatment before Sowing | Notes |
|---|---|---|
| Ash | If picked in dry sunny weather, no further treatment is necessary. Stratify for 16–18 months before sowing in March or April. | Seed collected green in July or August and sown immediately will usually germinate the following spring, but yield is erratic. Requires neutral soil for good growth. |
| Beech (European) | Store dry in layer 8 inch/20 *cm* deep and turn over occasionally. Spray lightly from January or early February to keep seed plump. Alternatively, may be cold stored at —5°C until sown. Alternatively, store dry until mid-February, then stratify for three weeks. Sow early March to mid March | Seed should not be allowed to sweat or heat up immediately after collection. Large quantities should be spread out no more than six inches deep initially, and will need to be turned frequently. Examine daily for the first two-three weeks after collection. Heating and sweating causes seed coats to blacken. Autumn sowing is satisfactory if soil is free-draining and the site not prone to late spring frosts. |
| Birch, *Betula* species | Store dry in sealed container in cold store. Alternatively, may be stratified for two or three months before sowing in March, or early April. | Very sensitive to seedbed surface conditions. Smooth well-firmed surface, even, light covering and wet conditions give best results. Water in dry weather, for 2–3 weeks after sowing. |
| Broom | Store dry until required then boil a volume of water not more than 5 times the volume of the seed, put the seed in a bowl, pour boiling water over it and leave until cool. Seed can be red-leaded afterwards if desired. Sow end March or early April. | Hot water treatment is more reliable than alternative of soaking in cold water for 7 days. |
| Cherry, *Prunus* species including Gean and Bird cherry | Stratify for four months and sow in March or early April, or sow in November or sow immediately after collection. | Seed should be kept in airtight container in a cool place between the time of extraction from the fruit and sowing or stratification. |
| Chestnut, Horse | Sow immediately after collection or stratify until spring. | |
| Chestnut, Sweet or Spanish | Store as for oak. | |
| Elm—Wych | Avoid storage if possible, otherwise keep cool and avoid drying. Storage mixed with sawdust has been successful. | Sow immediately after collection, the same day if possible. Water seed after sowing and before covering to prevent seed jumping when covered. Water on dry days in week after sowing. |
| Elm—other species of *Ulmus* | Other elms growing in Britain flower very early and flowers are damaged by frost and so usually fail to set seed. If trees have apparently set good seed, it should be treated as for Wych elm. Many elms sucker freely and may be propagated from suckers or from cuttings. | |
| *Eucalyptus* species | *Eucalyptus* seed is very small and viability varies considerably. When stored dry the seed remains viable for up to two or three years. Seed should be sown thinly in seed pans or boxes, covered with coarse sand and put in a cold-frame. Seedlings should be pricked out when big enough to handle into 3-inch pots. Plants must be protected against frost in the first winter. | |

*(continued)*

TABLE 22—*continued*

| Species | Treatment before Sowing | Notes |
|---|---|---|
| False acacia | Store dry until sowing. Then treat as for broom. | Seed pods when ripe should be picked from trees. Access may be difficult. Seedlings can grow to 30 inches tall in favourable years. |
| Field maple | As for sycamore, but stratify for 16–18 months | *var. hebecarpum*, the more common variety, has downy fruits. *var. lerocarpum* has smooth fruits. Less vigorous than sycamore. |
| Hawthorn (Syn. Whitethorn, May), *Crataegus* species | Crush pulp and wash away from seed. Stratify seed for 16 months. | |
| Hazel | Stratify for 3 to 4 months. Sow in early April. | |
| Hickory, *Carya* species | Seed imported dry in the spring has given poor yields. Small fresh sample imported in moist peat did well. | Slow in nursery. |
| Holly | Crush pulp and wash from fruit. Stratify in sand for 16 months. Alternatively, stratify berries whole. | Male and female flowers on separate trees. Lift when roots actively growing and soil warm. Ornamental varieties may be propagated by rooting in heated frames from half-ripened side shoots four inches long with a heel of old wood, or by layering or by budding. |
| Hornbeam | Stratify for one year before sowing. | |
| Indian bean, *Catalpa* species | Sow dry or 2–3 months stratification. | Seedlings become suppressed if beds are overcrowded. Seedlings usually die back two to three inches in their first winter. |
| Lime, *Tilia* species Common lime, Small leaved lime, Large leaved lime | Stratify for 16–18 months | The common lime seldom produces fertile seed in this country. |
| Norway maple | See sycamore | |
| Oak, Pedunculate, Oak, Sessile | Store in cool, well ventilated place—proof against vermin. Seed may be in heaps which should be turned every three weeks. In the new year, a close watch should be kept for shrivelling and if the first signs are observed, seeds should be sprinkled with water to keep them plump until sowing in late March. | Damaged tips to radicles do not apparently affect germination. May be sown in the autumn if soil well drained and bird damage unlikely to be severe. Cover with 3–4 inches extra soil and remove this in March. |
| Plane, London<br><br>Occidental plane<br>Oriental plane | Propagated vegetatively. See Section 12.2 | Low germination percentage.<br><br>Water in dry spells until established. |
| Rowan (Syn. Mountain ash) also Whitebeam and Swedish Whitebeam, *Sorbus* species | Macerate berries and separate fruit from seed. Stratify after collection and sow in the following spring. | If seed is not separated from fruit, it may remain dormant for an additional year. |

(*continued*)

TABLE 22—*continued*

| Species | Treatment before Sowing | Notes |
|---|---|---|
| Southern beeches, *Nothofagus* species | Store dry. Stratify for three weeks in early March. | |
| Spindle Tree | Stratify between time of collection and sowing in March. | |
| Sycamore, also Norway maple and other *Acer* species (For Field maple, see page 61) | Sow immediately after collection or store dry in cool store until the end of February, when stratify for eight weeks. | If stratified too soon, seed may germinate too soon when beds not fit to be sown. |
| Tree of Heaven | | Plants succulent at the end of year and usually die back to some extent. Protect against early autumn frost. |
| Tulip Tree | Stratify after harvesting for 6 months. | |
| Walnut, Common<br>Walnut, Black | Stratify immediately after harvesting until the spring. Sow when seed on point of germinating, rejecting any bad nuts. | Small nuts often fail to germinate and low yields obtained if small nuts predominate in seed lot.<br>Heavy manuring in near neutral soil required for good nursery stock. Plants usually remain in beds to 2 + 0. Special care is required on lifting, trimming cleanly any torn roots. After transplanting at 2 ft x 2 ft, trees with diameter of 3/4 inches or more should be cut back to 1 inch above the root collar. This ensures a vigorous straight stem. Leave for two years in lines, shortening laterals if necessary in July or August to ensure vigorous leader growth. |

*Footnote.* These recommendations relate to seed collected and treated locally. Often seed collected and processed where there are facilities for controlled drying of seed in bulk, retains its viability for longer than can be expected in the absence of such facilities.

Tables 21 and 22 set out general recommendations for sowing. These provide a guide in the absence of good local experience, but in particular nurseries it may be found by trial and error that sowing dates are best brought forward or delayed according to local conditions.

### 7.32 Sowing Density

The density at which seed should be sown depends on many factors. Those such as the variation in seed quality, the known productivity of the nursery, local techniques (e.g. drill or broadcast sowing), and preference for either one-year or two-year old seedling stock, can be taken into account when deciding the density of sowing. In contrast, seasonal factors such as distribution of summer rainfall and critical spells of drought cannot be predicted but have a profound effect on nursery yields. Because of these factors, it is not possible to make precise forecasts of seedling yields from given densities of sowing. Some estimates of the yield of usable seedlings are given in columns 14 and 15 of tables 23a and 23b and column 7 of table 24. It must be realised however, that figures are averages and that variations of $\pm$ 25 per cent are commonplace.

The densities prescribed in the tables are designed to give fully stocked seedbeds in average seasons in productive nurseries. Some degree of over-crowding can be brought about by seedlings being taller than average and by high stocking, or both; this can be expected in seasons when germination and growth are good. However, periodic slight over-crowding is inevitable if seedbeds are not to be understocked in all except the most favourable seasons. There is no evidence that the yield of usable plants is reduced in good seasons because of overcrowding following sowing at the densities recommended; the percentages of culls may be somewhat higher, but the total number of usable plants from a given number of viable seeds is usually above average in a good season in spite of apparently crowded beds.

TABLE 23a

CONIFER SEED QUALITY, SOWING DENSITY AND EXPECTED YIELD

MAJOR CONIFERS

IMPERIAL UNITS
(*See Table 23b for metric equivalents*)

| Common Name (For Botanical Name see Appendix VII) | Seed Qualities | | | | Sowing density for normal quality seed | | | | Expected yield in productive nurseries | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. of pure seeds per lb (1 000s) | Germination percentage Good Standard | Germination percentage Low | No. of viable seeds per lb (1 000s) | No. of viable seeds per sq yard (1 000s) | | Sq yd per lb (E) of seed | | Total No. of seedlings per sq yd at end of season | | Average height of usable seedlings at end of season (inches) | | No. of usable seedlings at end of season per lb (E) (1 000s) | | Germination Survival Factor Col 10 ÷ Col 6 | Germination Survival Factor Col 11 ÷ Col 7 |
| (1) | (2) | (3) | (4) | (5) | (6) To raise 1+0 seedlings | (7) To raise 2+0 seedlings | (8) 1+0 | (9) 2+0 | (10) 1+0 | (11) 2+0 | (12) 1+0 | (13) 2+0 | (14) 1+0 | (15) 2+0 | (16) 1+0 | (17) 2+0 |
| Scots pine | 75 | 85 | 50 | 64 | 1.0 | 0.8 | 64 | 80 | 500 | 360 | 2–4 | 3–6 | 29 | 26 | 0.5 | 0.45 |
| Corsican pine | 32 | 80 | 50 | 25 | 0.5 | 0.4 | 50 | 62 | 350 | 240 | 2–3 | 3–6 | 16 | 14 | 0.7 | 0.6 |
| Lodgepole pine | 135 | 90 | 50 | 120 | 1.0 | 0.8 | 120 | 150 | 500 | 360 | 2–4 | 3–6 | 54 | 48 | 0.5 | 0.45 |
| European larch | 76 | 35 | 15 | 26 | 0.8 | (0.65) | 32 | (40) | 480 | (300) | 4–7 | (5–9) | 16 | 14 | 0.6 | 0.5 |
| Japanese larch | 113 | 40 | 20 | 45 | 0.7 | (0.5) | 64 | (90) | 490 | (300) | 4–8 | (5–10) | 29 | 25 | 0.7 | 0.6 |
| Hybrid larch | 95 | 25 | 10 | 24 | 0.8 | (0.65) | 30 | (36) | 480 | (300) | 4–8 | (5–10) | 13 | 10 | 0.6 | 0.5 |
| Douglas fir | 40 | 80 | 50 | 32 | 0.8 | (0.65) | 40 | (50) | 400 | (200) | 3–6 | (4–8) | 14 | 11 | 0.5 | 0.4 |
| Norway spruce | 65 | 80 | 50 | 52 | 1.3 | 0.95 | 43 | 95 | 780 | 470 | 1½–2½ | 4–6 | 26 | 23 | 0.65 | 0.5 |
| Sitka spruce | 180 | 80 | 50 | 144 | 1.4 | 1.0 | 100 | 144 | 900 | 600 | 1½–3 | 4–6 | 72 | 65 | 0.65 | 0.6 |
| Grand fir | 20 | 40 | 15 | 8 | 0.6 | 0.5 | 13 | 16 | 360 | 300 | 1½–2½ | 2½–4 | 4 | 4 | 0.65 | 0.6 |
| Noble fir | 18 | 30 | 15 | 6 | 0.8 | 0.6 | 7 | 10 | 480 | 300 | 1½–2½ | 2½–4 | 2 | 3 | 0.6 | 0.5 |
| Western hemlock | 293 | 65 | 30 | 190 | 2.0 | 1.6 | 95 | 119 | 900 | 300 | 2–3 | 4–8 | 66 | 57 | 0.45 | 0.3 |
| Western red cedar | 383 | 60 | 30 | 230 | 2.0 | 1.6 | 115 | 143 | 900 | 500 | 2–3 | 4–7 | 80 | 69 | 0.45 | 0.3 |
| Lawson cypress | 207 | 50 | 30 | 103 | 1.3 | 1.6 | 79 | 64 | 780 | 500 | 2–3 | 4–7 | 51 | 46 | 0.6 | 0.3 |

*Notes.* Figures in brackets in columns 7, 9, 11, 13 and 17 refer to species which are not normally sown to raise 2+0 stock.

1 lb (E) = AN EFFECTIVE POUND. This is a pound of seed containing a stipulated number of viable seeds as given in column 5, which is equal to the number of viable seed in one pound of "Good Standard" seed.

TABLE 23b

SEED QUALITY, SOWING DENSITY AND EXPECTED YIELDS

MAJOR CONIFERS

METRIC EQUIVALENTS *(See table 23a for Imperial equivalents)*

| Common Name (See Appendix VII for botanical names) | Seed Qualities | | | | Sowing Density for Good Standard Seed | | | | Expected Yield in Productive Nurseries | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Average No. of pure seeds per kg (1 000s) | Germination Percentage Good | Germination Percentage Low Standard | No. of viable seeds per kg (1 000s) | No. of viable seeds per sq m (1 000s) | | Sq m per kg (E) of seed | | Total number seedlings per sq m at end of season (1 000s) | | Average height of usable seedlings at end of season cm | | No. of usable seedlings at end of season per Kg (E) (1 000s) | | Germination survival factor Col 10 ÷ Col 6 | Germination survival factor Col 11 ÷ Col 7 |
| (1) | (2) | (3) | (4) | (5) | (6) To raise 1+0 seedlings | (7) To raise 2+0 seedlings | (8) 1+0 | (9) 2+0 | (10) 1+0 | (11) 2+0 | (12) 1+0 | (13) 2+0 | (14) 1+0 | (15) 2+0 | (16) 1+0 | (17) 2+0 |
| Scots pine | 165 | 85 | 50 | 140 | 1.2 | 0.95 | 117 | 147 | 0.6 | 0.4 | 5–10 | 8–15 | 63 | 56 | 0.5 | 0.45 |
| Corsican pine | 70 | 80 | 50 | 55 | 0.6 | 0.5 | 92 | 100 | 0.4 | 0.3 | 5–8 | 8–15 | 36 | 30 | 0.7 | 0.6 |
| Lodgepole pine | 300 | 90 | 50 | 270 | 1.2 | 0.95 | 225 | 284 | 0.6 | 0.4 | 5–10 | 8–15 | 121 | 108 | 0.5 | 0.45 |
| European larch | 170 | 35 | 15 | 60 | 1.0 | (0.8) | 60 | (75) | 0.6 | (0.40) | 10–20 | (12–25) | 36 | 33 | 0.6 | (0.5) |
| Japanese larch | 250 | 40 | 20 | 100 | 0.9 | (0.6) | 111 | (167) | 0.6 | (0.35) | 10–20 | (12–25) | 65 | 55 | 0.7 | (0.6) |
| Hybrid larch | 210 | 25 | 10 | 50 | 1.0 | (0.8) | 50 | (63) | 0.6 | (0.40) | 10–20 | (12–25) | 27 | 20 | 0.6 | (0.5) |
| Douglas fir | 88 | 80 | 50 | 70 | 1.0 | (0.8) | 70 | (88) | 0.5 | (0.3) | 7–15 | (10–20) | 31 | 24 | 0.5 | (0.4) |
| Norway spruce | 145 | 80 | 50 | 110 | 1.4 | 1.1 | 79 | 100 | 0.9 | 5.5 | 4–7 | 10–15 | 55 | 49 | 0.65 | 0.5 |
| Sitka spruce | 400 | 80 | 50 | 320 | 1.7 | 1.3 | 188 | 246 | 1.1 | 0.8 | 4–8 | 10–15 | 160 | 144 | 0.65 | 0.6 |
| Grand fir | 45 | 40 | 15 | 20 | 0.8 | 0.6 | 25 | 33 | 0.5 | 0.35 | 4–8 | 7–15 | 10 | 10 | 0.65 | 0.6 |
| Noble fir | 40 | 30 | 15 | 12 | 1.0 | 0.8 | 12 | 15 | 0.6 | 0.4 | 4–7 | 7–10 | 5 | 5 | 0.6 | 0.5 |
| Western hemlock | 650 | 65 | 30 | 420 | 2.4 | 2.0 | 175 | 210 | 1.1 | 0.6 | 5–8 | 10–20 | 145 | 125 | 0.45 | 0.3 |
| Western red cedar | 850 | 60 | 30 | 500 | 2.4 | 2.0 | 208 | 250 | 1.1 | 0.6 | 5–8 | 10–18 | 175 | 150 | 0.45 | 0.3 |
| Lawson cypress | 460 | 50 | 30 | 230 | 1.5 | 1.2 | 153 | 192 | 0.9 | 0.6 | 5–8 | 10–18 | 115 | 103 | 0.6 | 0.5 |

*Notes.* Figures in brackets in columns 7, 9, 11, 13 and 17 refer to species which are not normally sown to raise 2+0 stock.

1 kg (E) = AN EFFECTIVE KILOGRAMME.

1 kg (E) contains the number of viable seeds given in Col 5, i.e. the number of viable seed in 1 kg of "Good Standard" Seed.

TABLE 24

SEED QUALITY AND SEEDLING PRODUCTION—HARDWOODS

| Common Name (For Botanical Name see Appendix VII) (1) | Average number of seeds per lb/*per kg* (2) | Average Purity % (3) | Average Germination % (4) | No. of viable seeds per sq yd/ *sq m* at sowing (5) | No. of sq yds sown area per lb of seed/*sq m per kg* (6) | Average yield of seedlings per lb/*kg* of seed sown (7) | Average height of seedlings at 1+0 (inches/ *cm*) (8) |
|---|---|---|---|---|---|---|---|
| *Ailanthus*—see Tree of Heaven | | | | | | | |
| Alder— | | | | | | | |
| Common alder | 350 000/*770 000* | 80 | 35 | 2 000/*2 400* | 60/*110* | 30 000/*66 000* | 3–8/*7–20* |
| Green alder | 165 000/*363 000* | 80 | 50 | 1 700/*2 000* | 50/*90* | 25 000/*60 000* | 3–8/*7–20* |
| Grey alder | 500 000/*1 000 000* | 80 | 25 | 2 000/*2 400* | 60/*110* | 30 000/*60 000* | 3–8/*7–20* |
| Red or Oregon alder | 600 000/*1 300 000* | 75 | 35 | 2 000/*2 400* | 100/*180* | 50 000/*110 000* | 3–8/*7–20* |
| Ash | 7 000/*15 000* | 90 | 70 | 500/*600* | 10/*18* | 1 200/*2 500* | 4–9/*10–22* |
| Beech | 1 900/*4 200* | 95 | 60 | 600/*700* | 2/*4* | 600/*1 300* | 4–8/*10–20* |
| Birches— | | | | | | | |
| Paper birch | 1 000 000/*2 200 000* | 60 | 35 | 4 000/*4 800* | 90/*160* | 35 000/*75 000* | 2–8/*5–20* |
| Common birch | | | | | | | |
| *Betula pendula* | 1 100 000/*2 400 000* | 30 | 40 | 4 000/*4 800* | 110/*200* | 45 000/*100 000* | 3–8/*7–20* |
| *Betula pubescens* | 1 200 000/*2 700 000* | 30 | 40 | 4 000/*4 800* | 120/*220* | 48 000/*105 000* | 3–8/*7–20* |
| Broom | 70 000/*150 000* | 100 | 80 | 800/*1 000* | 70/*125* | 22 000/*50 000* | 4–10/*8–25* |
| *Catalpa*—see Indian bean | | | | | | | |
| Cherry— | | | | | | | |
| Bird cherry | 6 500/*14 000* | | | 800/*1 000* | (5)/*(9)* | (500)/*(1 000)* | (4–6)/*(10–15)* |
| Gean or Wild cherry | 3 000/*6 600* | 98 | 80 | 800/*1 000* | 3/*6* | 500/*1 100* | 4–6/*10–15* |
| Chestnut— | | | | | | | |
| Horse chestnut | 30–120/*70–260* | 100 | 75 | 100/ *120* | 0.5/*1* | 20/*45* | 6–10/ *15–25* |
| Sweet chestnut | 70–130/*150–290* | 100 | 75 | 80/*100* | 0.8/*1.5* | 50/*110* | 5–12/ *12–30* |
| Elm— | | | | | | | |
| Wych elm | 48 000/*105 000* | (95) | 40 | 500/*600* | 40/*70* | 9 000/*20 000* | 4–8/*10–20* |
| False acacia | 24 000/*53 000* | 97 | 70 | 600/*720* | 30/*55* | 3 500/*7 500* | 15–24/ *35–60* |
| Gean—see Cherry | | | | | | | |
| Hawthorn | 3–6 000/*6–13 000* | (—) | (—) | (—) | 5/*9* | (600)/*(1 300)* | 4–8/*10–20* |
| Hazel | 400/*900* | 100 | (80) | 400/*480* | 1/*2* | 80/*180* | 4–6/*10–15* |
| Hickory, *Carya* species | 50–200/*110–240* | 100 | (80) | 80/*100* | 1/*2* | (40)/*90* | (4)/*(10)* |
| Holly | 20 000/*45 000* | (—) | (80) | 1 000/*1 200* | 16/*30* | 4 000/*9 000* | 2–5/*5–12* |
| Hornbeam | 8 000/*17 500* | 95 | 45 | 500/*600* | 7/*12* | 1 400/*3 000* | 2–4/*5–10* |
| Indian bean | 20 000/*45 000* | 60 | 75 | 300/*360* | 50/*90* | 4 000/*9 000* | 5–10/ *12–24* |
| Limes— | | | | | | | |
| Large-leaved lime | 3 500/*7 500* | (—) | 70 | 800/*1 000* | 2.5/*5* | 250/*550* | 5–8/*12–20* |
| Small-leaved lime | 13 000/*29 000* | 95 | 70 | 800/*1 000* | 12/*22* | 900/*2 000* | 6–10/ *15–25* |
| Maple and sycamore— | | | | | | | |
| Field maple | 7 000/*15 000* | 90 | 80 | 400/*480* | 14/*25* | 1 500/*3 300* | 3–8/*7–20* |
| Norway maple | 3 500/*7 500* | 90 | 80 | 300/*360* | 10/*18* | 1 000/*2 000* | 6–12/*15–30* |
| Sycamore | 4 000/*9 000* | 90 | 80 | 200/*240* | 16/*30* | 1 000/*2 200* | 8–18+/ *20–50+* |

*(continued)*

TABLE 24—*continued*

| Common Name —Botanical Name (1) | Average number of seeds per lb/*per kg* (2) | Average Purity % (3) | Average Germination % (4) | No. of viable seeds per sq yd/ *sq m* at sowing (5) | No. of sq yds sown area per lb of seed/*sq m per kg* (6) | Average yield of seedlings per lb/*kg* of seed sown (7) | Average height of seedlings at 1+0 (inches/ *cm*) (8) |
|---|---|---|---|---|---|---|---|
| Oaks— | | | | | | | |
| Pedunculate oak | 50–200/*110–450* | 90 | 80 | 250/*300* | 0.5/*1* | 80/*180* | 4–8/*10–20* |
| Red oak | 80–250/*180–550* | 90 | 80 | 250/*300* | 0.5/*1* | 75/*160* | 5–9/*12–22* |
| Sessile oak | 60–220/*130–500* | 90 | 80 | 250/*300* | 0.5/*1* | 80/*180* | 4–8/*10–20* |
| Plane, American or Buttonwood | 180 000/*400 000* | (—) | (low) | (—) | (20)/(*36*) | (8 000)/(*18 000*) | (2–6)/ (*5–15*) |
| Oriental plane | 110 000/*240 000* | (—) | (low) | (—) | (10)/(*18*) | (400)/(*900*) | (2–6)/ (*5–15*) |
| London plane— (See also Section 12.2) | (100 000)/(*220 000*) | (—) | 35 | 2 300/*2 800* | (15)/(*27*) | (1 000)/(*2 200*) | (2–6)/ (*5–15*) |
| Rowan | 130 000/*280 000* (2 400 per lb of fruit/ *5 000 per kg*) | (96) | (70) | (2 000/(*2 400*) | (50)/(*90*) | (3 600)/(*8 000*) | (3–9/) (*7–25*) |
| Whitebeam | (—) (700 per lb of fruit/ *1 500 per kg*) | (—) | (—) | (—) | (10)/(*18*) | (1 000)/(*2 200*) | (3–9)/ (*7–25*) |
| Southern beeches | | | | | | | |
| Roble, *N.*obliqua.* | 55 000/*120 000* | 85 | 25 | 900/*1 100* | 16/*30* | 2 400/*5 200* | 7–10/*17–25* |
| Rauli, *N.*procera.* | 47 000/*100 000* | 85 | 33 | 900/*1 100* | 18/*32* | 2 700/*6 000* | 6–9/*15–25* |
| Spindle Tree | 10 000/*22 000* | 90 | 80 | 300/*360* | 27/*48* | 4 000/*9 000* | 3–6/*7–15* |
| Sycamore—see Maple | | | | | | | |
| Tree of heaven | 14 000/*30 000* | (88) | 80 | 250/*300* | 45/*80* | 4 500/*10 000* | 6–9/*15–25* |
| Tulip tree | 12 000/*26 000* | 75 | 20 | 500/*600* | 4/*8* | 150/*330* | 2–6/*5–15* |
| Walnut— | | | | | | | |
| Black walnut | 30–150/*65–330* | 100 | 75 | 36/*43* | 2/*4* | 50/*110* | 5–12/*12–30* |
| Common walnut | 30–80/*65–180* | 100 | 75 | 36/*43* | 1/*2* | 25/*55* | 5–10/*12–25* |

*Notes:* Figures in brackets are based on limited evidence.
Brackets without figures (—) signifies that no reliable data are available.
*N.—*Nothofagus* or Southern beech.

The recommended densities of sowing for the production of 1 year and 2 year conifer seedlings are given in table 23a in terms of viable seeds per square yard, columns 6 and 7, and square yards per "effective" pound of seed in columns 8 and 9. (For a definition of an "effective" pound of seed see Section 6.58). The expected stocking of seedbeds and height of seedlings at the end of season are given in columns 10 to 13, while average germination/survival factors (the proportion of viable seeds which germinate and grow to 1-year or 2-year seedlings, both usable or unusable) are given in columns 16 and 17. Corresponding metric values are given in Table 23b.

### CALCULATION OF NORMAL SOWING DENSITY

The normal **broadcast** sowing density of seed of any known number of viable seeds per pound may be calculated by dividing the number of viable seeds per pound by the number of viable seeds per square yard in Tables 23a or 24. This gives a figure for sowing density in square yards per pound.

**N.B.** If densities in *metric* units are required, the same calculation can be made using figures in Tables 23b or 24. Alternatively, the figure of the number of square yards per lb may be doubled when it will be the appropriate number of square metres over which to sow one kg of seed.

Adjustments to the normal broadcast sowing density may be made as follows:

(*i*) *Drill Sowings:* If seed is to be sown in drills, the sowing area per pound of seed calculated as above should be increased by 25 per cent;

(*ii*) *Low Quality Seed:* Should the germination percentage fall below the value given in column 4 of the table, the calculated area per pound should be reduced by 20 per cent.

(*iii*) *Local Experience:* Experience in a particular nursery may indicate that growth, or germination and survival of a particular species, is consistently higher or lower than normal. This may be allowed for as follows:

(*a*) If seedlings of any particular species at 1 year or 2 years are regularly 20 to 35 per cent taller than average (for conifers, see columns 12 and 13, Table 23a), increase the sowing area by 33 per cent. If regularly 35 to 50 per cent taller, increase the sowing area by 66 per cent.

(*b*) Where the germination/survival factor of conifer sowings regularly departs by 20 per cent or more from the value given in columns 16 and 17, the sowing area should be increased or decreased in proportion.

*Example:* To determine the sowing area for 1 pound of Sitka spruce seed with 70 per cent germination and 150 000 viable seeds per pound, to be sown broadcast to produce 1-year seedlings.

First step, calculate sowing area at normal broadcast sowing density:

$$\text{Sowing area} = \frac{\text{Number of viable seeds per lb}}{\text{Recommended number of viable seeds per sq yd}} = \frac{150\,000^{*}}{1\,400^{**}}$$

$$= 107 \text{ sq yd per pound}$$

* Figure available with seed

** Column 6: Table 23a.

For broadcast sowing, no further calculation is necessary, but for drill sowing for one-year seedling production, the area per pound should be increased by 25 per cent, and in this case the second step is:

$$107 \times \frac{125}{100} = 133.75 \text{ sq yd, say } 134 \text{ sq yd per pound}$$

*Cut-test Estimation*

If seed has to be sown when the laboratory figures for germination per cent and the number of seed per lb are neither available, as may happen when seed has been collected locally, the sowing density will have to be estimated by a "cut-test" of the seed. This is made as follows:

Thoroughly mix the seed and take 100 seeds selected by sampling as described in Section 6.51. The sample seed should be cut straight across with a sharp knife and examined for soundness. The kernel of a sound seed should completely fill the seed case and should be creamy white in colour. The number of sound seed should be reduced by 10 to allow for any seeds which appear sound but which may not be viable. This figure is then used as the germination percentage.

*Example:* 3 pounds of Scots pine seed for broadcast sowing to produce 1-year seedlings. If there are 80 sound seeds by cut-test, the estimated germination percentage is 80—10 i.e. 70 per cent: From table 23, the normal germination percentage for Scots pine is 90 per cent which is equivalent to 67 000 viable seeds per pound of average quality seed. In the absence of any other information, it has to be assumed that the seed in question contains $\frac{70}{90} \times 67\,000 = 52\,000$ viable seeds per pound approximately. Such seed should be sown at the rate of $\frac{52\,000}{1\,000} = 52$ square yards per pound of seed or near enough 150 yards for three pounds of seed.

### 7.33 Broadcast and Drill Sowing

Plates 3 to 5, 8 and 9.

In all sowing, the aim is to distribute seed as evenly as possible over the sown area or along the drill, so that each seedling has the same space in which to grow. All conifer seed and all hardwood seed, except for large seeded species are sown on the soil surface.

Whether seed should be sown broadcast or in drills is a matter of local opinion and experience and will be influenced by the skilled workers and by the type of machinery available for sowing and for subsequent cultivation. Beds sown broadcast generally carry 25 per cent more seedlings per unit area of seedbed than drill-sown beds.

However beds are sown, it is worth while leaving three inches/8 *cm* unsown on each edge of the bed. During the season, the edges usually crumble away and any seedlings growing there may be lost.

The sowing techniques described below can be used for most conifer and many smaller hardwood seeds. There are however exceptions; stratified seed is damp and bulky; it is not easily sown by machine, and may have to be sown by hand. The large seeded hardwoods which are covered with soil cannot be sown by the machines designed for conifer seed and the techniques for such seed are described at the end of this section.

BROADCAST SOWING

Seed may be broadcast by hand or by machine.

*Broadcast sowing by hand*

Where seed is sown by hand, it may be sprinkled or cast over the bed, so that it does not fall beyond the edges of the bed, or it may be cast or thrown diagonally across the bed so that some of the seeds rebound from a wooden "bouncing" board between 8 and 24 inches/*20 and 60 cm* high by about 3 feet/ *1 m* long. The board is held vertically with one edge on the edge of the sowing area and is moved along as sowing proceeds (Plate 4). Best results come from casting seed but small-winged seed like that of Lawson cypress can only be sprinkled.

Whether or not a board is used, best results are obtained if the seed for a bed is divided into two equal parts and one part sown working from one side and the other from the other side of the seedbed. The most uniform sowing by hand can only be achieved by practice. Novices at sowing must expect some unevenly distributed seed.

*Broadcast sowing by machine*

The machines most commonly used for seed sowing were originally designed to spread fertiliser and sow lawn seed. They may be drawn by hand or by tractor and consist of a hopper on wheels. At the base of the hopper is a moving belt which carries seeds out at a rate regulated by a metal slide or gate. Seed is brushed off the belt to ensure uniform distribution. (Plate 5).

The Ledmore seed sower, though designed for drill sowing can be modified to sow broadcast. (Plate 8).

DRILL SOWING

Drill sowings are preferred where machines are available to cultivate between the drills in a bed or where seedlings are being raised for under- and side-cutting.

Where seed is sown by hand, the lines for the drills may be marked out by hand across the bed at suitable intervals using a lath one inch wide and approximately ¼ inch/*2.5* x *0.6 cm* thick. This will give a drill depth of three-sixteenths of an inch/ *0.4 cm*. Alternatively the bed can be marked using a roller with ¼ inch by 1 inch/*0.6 x 2.5 cm* rubber bands round the periphery of the roller at regular intervals. Known amounts of seed per drill or length of drill are best put in any convenient tube or bottle for sowing.

For mechanical drill sowing, several machines have been made up from parts of agricultural drills. Plate 8 illustrates a drill sower developed at Ledmore nursery near Perth. Inside each hopper, a shaft carrying bristles and spoons rotates, ensuring that seed flows through an adjustable aperture near the base of each hopper and down a tube to a drill-shoe.

More recently, the hopper and feed mechanism have been adapted to fit onto the large hoppers used for carrying the grit seedbed covering, thereby disposing of the need for a special frame.

### 7.34 Hardwood Seed

Details of treatment of seed in preparation for sowing are given in table 22.

Whereas almost all other forest tree species are best sown on the soil surface and covered with sand or grit, the seed of the larger seeded hardwoods such as oak, beech and sweet chestnut are best sown and covered with soil between one inch and one and a half inches/*2.5 to 4 cm* thick.

When sowing broadcast by hand, seed may be spread over the surface of the bed before the alleys are dug and the soil from the alleys may be spread evenly over the seed, covering it and enabling alleys to be made in one operation. The alleys so formed may be four inches/*10 cm* below the seedbed surface. If there is more soil covering than is required, the surplus may be taken away from the sowing area using rakes or "cuffing boards" i.e. flat boards roughly 4 inches x 18 inches/ *10 x 50 cm* on the end of long handles.

Large hardwood seeds may also be sown in bands between six and nine inches wide and a similar distance apart. Bands can be dug out by hand as for broadcast beds; they can also be prepared using a plough set very shallow to open the trench on the first pass and spread a shallow covering of soil in the next. Where seed is sown in such bands, alleys are often omitted. The roots of the large seeded hardwood species are often very robust; one advantage of band sowings is that if plants are lifted by hand, spades can be inserted deeply under the band from both sides to sever the roots.

### 7.35 Rolling After Sowing. Plate 7.

If the seed bounces up while being covered with grit after sowing, it should be pressed into the surface of the soil either by a light wooden roller, approximately 8 inches in diameter or by a light board 4 inches wide fitted to a broom handle. This is probably more necessary where grit cover is spread by hand than where a machine is used, the reason being that when covering by hand the grit has farther to fall and hits the ground with greater momentum.

### 7.36 Sowing Density for Undercutting

Where seedlings are to be undercut and planted subsequently without a period in transplant lines, it is essential for them to have more growing space than normal seedlings. The aim should be to produce a stocking between one third and one quarter of normal stocking (for normal stocking, see Tables 23a, 23b and 24). The main consequence of the increased space is that plants are sturdier and have better furnished side branches.

Careful control of the sowing density of seedbeds to be undercut is of critical importance in relation to the economics of undercutting; if poor germination follows sparse sowing, the undercut seedlings become prohibitively expensive. Seed-sowing machines have been developed at Ledmore nursery in east Scotland, Plate 9, and at Tair Onen nursery in South Wales, specifically to sow at low density in drills for undercutting.

Drill-sowing is only essential if plants are to be side-cut as well as undercut. Otherwise seed may be broadcast if this is the normal practice for the nursery.

See also Chapter 8, Section 8, page 83.

### 7.37 Grit Covering

Seed covered with coarse sand or fine grit germinates more quickly and gives higher yields than if nursery soil is used. If the nursery is sheltered, coarse sand is quite suitable but in many nurseries, sand may be blown off by wind and a fine grit passing a $\frac{1}{8}$ to $\frac{3}{16}$ inch/*3 to 5 mm* mesh is preferable.

In some localities, $\frac{1}{4}$ inch/*6 mm* grit is readily available but this grade of grit should only be used if nothing finer can be obtained. Where there is a choice between crushed flint and a rounded material of approximately the same size, the latter is preferable, especially in weedy nurseries, as workers' fingers may be cut by sharp edges in the crushed flints.

It is essential that the grit is free from silt and from lime. It is also preferable to use a light-coloured grit rather than a dark one. If the grit is silty, it will cake and may reduce the germination of seedlings; if it contains lime, it will ultimately ruin the nursery by making the soil reaction neutral or even alkaline when it should be acid. (Section 3.23). If in doubt, add dilute hydrochloric acid to a sample of the grit. If it fizzes, it contains too much lime to be used with safety.

The colour of the grit affects the temperature at the seed bed surface; black or dark-grey grit can be several degrees warmer at the soil surface on a hot day than a very light coloured grit. This could make the difference between severe heat injury to conifers at the root collar and little injury. Table 25 illustrates the effect of particle size and colour on the yields of seedlings in a hot summer. In the experiment from which these results are taken, maximum temperatures, recorded just under the grit, were 49°C and 55°C for the white and dark grey grits respectively.

TABLE 25

EFFECT OF THE COLOUR AND SIZE OF GRIT USED AS A SEEDBED COVERING ON THE YIELD OF SITKA SPRUCE SEEDLINGS PER SQUARE YARD: KENNINGTON NURSERY, OXFORD 1955

| Colour of Grit | Grade of Grit | | | | | |
|---|---|---|---|---|---|---|
| | Fine | | Medium | | Coarse | |
| | No.* | Ht.* ins | No. | Ht. ins | No. | Ht. ins |
| White | 636 | 1.8 | 684 | 1.8 | 244 | 1.2 |
| Light Grey | 256 | 0.9 | 354 | 1.2 | 314 | 1.2 |
| Dark Grey | 254 | 0.9 | 228 | 0.6 | 228 | 1.0 |

*To convert, multiply by 1.2 for numbers per sq m or 2.54 for height in cm.

The white grit was a quartz from St Austell, Cornwall; the light grey material was a granitic sand from Penmaenmawr, Caernarvonshire, and the dark grey material a basalt from Clee Hill, Shropshire. The particles in the fine material ranged from 0.2 to 2 mm diameter, the medium from 2–6 mm while the coarse particles were more than 6 mm in diameter.

The quantity of grit required depends on the size of the grit and the size of the seed. As a rough guide, the depth of covering required should slightly exceed the length of the seed on its longest axis. This should be sufficient to cover the seed so that it disappears completely from view. On average, one ton of grit should be expected to cover 100 sq yd/*84 sq m*, of conifer seed bed. For drills, it is more economical to cover only the drill and a strip one inch either side.

For large nurseries, grit boxes can be obtained either to fit the three-point linkage of a tractor or to be pulled by hand. See Plate 9. The grit runs out of the box in which it is held through an adjustable slit at the bottom of the box. This normally allows a layer of grit to be spread over the whole bed but baffles or stops can easily be made and fitted by the nurseryman so that drill sowings may be covered and part at least of the unsown interspace left uncovered. The cost of grit is quite substantial and the saving by this simple modification is well worth having.

When covering by hand, the grit should be wheeled to the beds in barrows. It is then shovelled onto ¼ inch/*6 mm* mesh riddles or sieves held chest high and shaken so as to distribute the grit evenly over the nearer half of the bed, the other half being covered from the other alley.

## 7.4 Subsequent Care

After beds have been sown and covered, weeds must be kept down, any insect, animal or fungal pests controlled, shelter or watering provided as necessary, and nitrogen fertiliser top-dressings applied.

### 7.41 Weed Control

The control of weeds is of paramount importance both for the best growth of the crop sown and for subsequent crops. Full details of materials and techniques for control of weeds are given in Chapter 10, page 92.

### 7.42 Protection against Pests, Sun and Frost

No protective measures have to be taken as a matter of routine. However, many troubles can affect seedbeds; these are described in Chapter 11, page 107, along with the appropriate remedies where these exist. The use of shelters against sun and frost is also described there.

### 7.43 Top-dressings

Nitrogen top-dressings will normally be required if seedlings are to grow well. In many nurseries, top-dressings of potassium fertilisers are also likely to be beneficial. The quantities to apply are set out in Section 4.2 while the timing of top-dressings is prescribed in Section 4.32.

## 7.5 Irrigation

Water can be applied in the late spring to assist germination of late-sown seed. If a prolonged period of warm dry weather follows sowing, irrigation will substantially enhance crop yields and growth. It is not so effective in speeding either germination of seed or growth of seedlings from early sowings as the soil is colder and lack of warmth appears to prevent germination as much as lack of moisture.

Irrigation has also been of value in enabling transplanting to continue in dry weather in the late spring and summer when otherwise it would have been impossible.

### 7.51 How Much Water to Apply and How Often

A soil well supplied with water can dry out if water is lost whether by evaporation from the soil surface or by extraction via plant roots and stems to leaves where it is transpired. These combined processes are often referred to as "evapotranspiration". The amount of water lost by evapotranspiration from a given soil at "field capacity" is often referred to as the "soil moisture deficit."

The aim in irrigation is to prevent the estimated soil moisture deficit from exceeding a particular value.

The need for irrigation in England and Wales may be estimated from the potential monthly water loss due to evapotranspiration given in Ministry of Agriculture Technical Bulletin No. 4, *Calculation of Irrigation Need.* For any area, these appear to be sufficient guide; there is no need to adjust the monthly average to the actual potential evapotranspiration as calculated from the weather data for that month. By the time this can be calculated it is almost always too late to make any effective corrections.

Calculation of potential water loss by evapotranspiration assumes that there is a full crop cover over the soil surface. In forest nurseries, this is seldom the case in first year seedbeds or lines until sometime in the summer. However, the rate of loss of water from a damp soil surface is almost as fast as from a soil surface covered with vegetation, at least until the equivalent of about half an inch of rainfall has been lost and the soil surface is dry.

During the germination period, the purpose of irrigation is to keep the soil surface moist. To make good the full potential loss by evapotranspiration during the germination period is somewhat extravagant of water but not so extravagant as might at first be thought.

To use the figures for the average monthly evapotranspiration, the monthly figure must be

TABLE 26

EXAMPLE OF AN IRRIGATION BALANCE SHEET

*South-east Oxfordshire: May, 1900*

| | |
|---|---|
| Monthly average loss by evapo-transpiration: | 3.00* |
| Daily average loss by evapo-transpiration: | 0.10 |

All figures in inches*

| Date | Daily average loss by evapo-transpiration | Rainfall in previous 24 hours | Irrigation | Running deficit | Notes |
|---|---|---|---|---|---|
| — | — | — | — | 0.07 | — |
| 13.5 | .10* | 0.00 | 0.00 | 0.17 | — |
| 14.5 | .10 | 0.00 | 0.00 | 0.27 | — |
| 15.5 | .10 | 0.00 | 0.20 | 0.00 | Seedbeds irrigated for 2 hours during day |
| 16.5 | .10 | 0.00 | 0.00 | 0.10 | — |
| 17.5 | .10 | 0.07 | 0.00 | 0.13 | — |
| 18.5 | .10 | 0.22 | 0.00 | 0.00 | — |
| 19.5 | .10 | 0.00 | 0.00 | 0.10 | — |
| 20.5 | .10 | 0.04 | 0.00 | 0.16 | — |

**Note.* The format of the table and method of use applies whether rainfall water loss and irrigation are calculated in inches or mm.

converted to a daily average loss, and a running balance sheet kept showing the accumulated nominal deficit. Irrigation should be applied to seedbeds whenever the deficit exceeds 0.25 inch/*6 mm* in the germination period and 0.5 inch/*12 mm* subsequently. The amount of water applied should equal approximately 70 per cent of the nominal deficit. After irrigation, it should be assumed that the deficit has been eliminated. An example is given in Table 26.

The balance sheet method of determining irrigation need can of course always be over-ridden or adjusted if the weather is exceptionally hot or cold or windy, remembering that during the germination period, sufficient water needs to be applied to keep the surface of the soil under the seedbed moist. If for any reason a balance sheet cannot be kept, much the same result in dry spells can be achieved by two applications a week of irrigation equivalent to ⅛ inch/*4 mm* of rain.

During the summer once there is a full crop of seedlings, half an inch/*12 mm* applied once a week during dry spells will probably suffice.

If transplants are to be irrigated at all, they should be watered the same way as for seedlings, i.e. little and often while they are getting established, with less frequent but heavier waterings during summer drought periods.

### 7.52 Water Supply and Distribution

Water should be soft and clean. Hard water used regularly raises the pH of the soil substantially. Instances of rises of 1 to 1½ units have been recorded and these are quite sufficient to depress growth of seedling conifers sensitive to soil reaction. Dirty water may lead to choked nozzles and blocked pipes.

A supply of water may be obtained from the mains, from rivers or from boreholes or wells according to local circumstances and may be distributed around the nursery by permanent buried pipes or by portable pipes which can be speedily clipped together.

Water can be distributed over seedbeds or transplant lines by oscillating spray lines (Plate 3) which cover a rectangular area or from rotary sprinklers which spray a circle. The more powerful rotary sprinklers must be avoided as the droplets they send out are heavy enough to disturb the grit of the seedbed surface. Any nurserymen contemplating installing an irrigation system should consult the local Agricultural Development Advisory Service horticultural adviser, or College of Agriculture in Scotland, and current catalogues for up-to-date information on irrigation equipment.

## 7.6 Special Techniques for Seedling Production

### 7.61 Production of Seedlings in tubes—"Tubelings"

This technique was first evolved in Canada and has been developed in Britain, mainly in Scotland, since 1968. Seedlings are raised in small plastic tubes which are planted directly in the forest, tubes, soil and seedling together, between eight and twelve weeks after sowing. On ploughed peatland, step-planted tubed seedlings survive well and make vigorous early growth; the effective planting season is thus extended from mid-April to late August. Very high planting rates have been achieved utilising a special planting tool. On such peat sites, the use of tubed seedlings could lead to large savings in peatland afforestation costs. The performance of tubed seedlings on ploughed mineral soils, however, has not been satisfactory, primarily due to severe damage by frost lifting (Low, 1971).

A greenhouse is necessary to achieve the controlled conditions essential for reliable tubeling production. The houses have to be able to provide day temperatures in the range 20° to 25°C and temperatures of 10° to 15°C at night. This can be achieved by thermostatically controlled warm air heating and fan ventilation. While glass greenhouses can be utilised for this purpose, polythene covered greenhouses have been quite adequate. In the British trials so far conducted, polythene houses 40 ft x 20 ft/*12 m* x *6 m* have been used.

In trials in Britain with Sitka spruce and Lodgepole pine, extruded polystyrene tubes 3 inches in length and ½ inch in internal diameter/*7.5 cm long* x *1.3 cm diameter*, and slit down one side have been used. These are packed in honeycomb formation in polystyrene seed-trays, each tray containing between 400 and 440 tubes. A mixture of equal parts by volume of finely milled sphagnum peat (screened through a 0.25 inch/*6 mm* mesh sieve) and a lime-free medium sand is used for filling the tubes and is added until approximately ½ inch/*1 cm* at the top of the tubes remains empty after the peat/sand mixture has been lightly compacted.

Two alternative fertiliser regimes can be used—one based on "Enmag" and the other on Fison's "FL 3 P" liquid fertiliser. In the first, 1½ oz of "Enmag", 2 oz of ground limestone and 0.2 oz of fritted trace elements per cubic foot are mixed intimately with peat and sand before the tubes are filled (1.5, 2.0 *and* 0.2 *kg per cu m of mixture*). Fritted trace elements may be purchased from Tennant Trading Limited, Lineharp Lane, Great Tower Street, London E.C.3. under the brand name "Frit 253 A". Where this mixture is used, no subsequent fertilising is required. In the alternative regime, ground magnesian limestone at 2.0 ounces and fritted trace elements at 0.2 ounce per cubic ft are added to the peat/sand mixture before filling the tubes. Subsequently, tubes are watered with a solution containing Fisons "FL 3 P" at a dilution of ½ fluid ounce per gallon/*3 ml per litre*, applied at weekly intervals beginning three weeks after sowing, using ½ gallon of solution per square yard of bench space/2.5 *l/sq m*. In trials, the "Enmag" regime has been found more convenient to use and to give greater average vigour while the FL 3 P regime gives a slightly higher seedling yield and very uniform growth.

The seed to be used should be of the maximum possible viability because only one seed is sown per tube. More uniform germination and regular growth can be achieved if the lightest seed can be selected out by means of a vibrating gravity table and discarded for this purpose. If the seed is believed to be any degree dormant, it should be moist pre-chilled before sowing. Otherwise, seed should be soaked for 24 hours in cold water (3° to 5°C) before sowing.

Immediately after sowing, the seed should be covered with a layer of medium sand, ⅛ inch/*3 mm* thick for Lodgepole pine, Sitka spruce and other small-seeded species; ¼ inch/*6 mm* thick for large seeded species such as Grand fir. Sand with a high proportion of very fine particles should be avoided, since such sand can cake and thereby reduce germination. The trays of tubes should then be stood in shallow water until the peat/sand mix is thoroughly moist, before being placed for seven days on racks at a steady 25°C in an insulated germination room of a type described by Newton and Gould, (1969). Trays must be covered with polythene sheeting to minimise water loss and should not require further watering during this period. Continuous light may be provided by a warm white fluorescent tube, but this is not essential.

After seven days, the trays are transferred to benches in a greenhouse where a day temperature of 21°C and night temperature of 10°C are maintained by thermostatically controlled heating and ventilation. Adequate forced draught ventilation is essential during sunny weather in summer. Using a fine spray, water should be applied whenever examination of the soil mix indicates. Watering should not be done in strong sunshine because of the risk of scalding damage to seedlings, and over-watering should be avoided as it leads to poor root development and may encourage damping off. As a precautionary measure against fungal attack, a Captan drench at 0.5 gallons per square yard/*2.5 litres/sq m* is normally applied two and four weeks after sowing; if the risk of damping off is high (e.g. in cool, damp weather in spring and autumn), additional applications may be given one and three weeks after sowing.

Prior to planting (usually six weeks after sowing) trays of seedlings should be placed out of doors to harden off for two weeks. During this period, netting protection is desirable to prevent damage by birds and mammals; hessian or other screening may be necessary, early and late in the growing season, in order to reduce the risk of frost damage. Before trays of tubes are despatched for planting, it is desirable to bring them up to full stocking by removing and replacing all tubes without seedlings or with weak, undersized seedlings. To ensure efficient use of greenhouse space, this is best done as early as possible in the production period. With an eight-week production period, sorting of Lodgepole pine and Sitka spruce could be done as early as three weeks after sowing, because seedlings germinating after that time are unlikely to be large enough for planting at eight weeks.

By following the above procedure and using seed with a high viability, 65 to 75 per cent of the tubes sown should contain a usable seedling after eight weeks. On average, seedling heights eight weeks after sowing are 1 inch/*2.5 cm* for pine and 0.8 inch/*2 cm* for spruce. Because of more favourable growing conditions, germination yield and growth rate all tend to be higher during the summer months (June to August) than at the beginning or the end of the season. In trials, seedlings have been allowed to grow for 12 weeks before planting in which case they are appreciably bigger; however, there has been insufficient advantage from the slightly larger tubelings to justify the additional period in the nursery.

### 7.62 Production of Seedlings in Paperpots

The techniques for raising seedlings in paper tubes or pots are similar to those described for 'tubelings' except that peat rather than sand-and-peat is used as the growing medium, and that plants remain in the greenhouse for three to four months.

Paperpots were developed in Japan in about 1960 for sugar beet seedlings. The paper consists of a mixture of natural and man-made fibres, the proportions being chosen to give grades with different breakdown times. For forestry, the most resistant grade, 'F', is used. The most suitable size is 3.8 cm diameter × 7.5 cm deep (JPP size 408). Paperpots are supplied stuck together with a water soluble glue and remain so until ready for use in the forest, when they can readily be separated.

### 7.63 The Dunemann Method of Seedling Production

The means of growing seedlings on leaf-litter provides a complete alternative to the conventional seedbed technique. The technique requires the establishment of conditions which are more than half way towards those of a propagating frame. A survey in 1962 of the extent to which the technique then had been adopted, showed Dunemann beds to have been successful in the large majority of nurseries where they had been established but that these in total area were less than one acre.

The essence of the technique is the provision of a well drained organic rooting medium in a boarded seedbed which is shaded and regularly watered. Large quantities of leaf litter are required for the rooting medium and this limits the scale on which the method can be applied. In 1962, no single nursery in Britain contained more than one-third of an acre of Dunemann seedbeds. Since then, the area under Dunemann beds has diminished rather than increased.

The quality of stock from Dunemann beds is satisfactory but plants develop bigger shoots for a given size of root than seedlings grown on mineral soil. Dunemann seedlings may be up to 30 per cent taller than seedlings from productive mineral soil seedbeds.

The total yield of plants from a given quantity of seed sown on Dunemann seedbed differs little from the total yield of plants on mineral soil seedbeds. However, almost all Dunemann seedlings are big enough to be lined out, so that the total yield of plants is also the yield of usable plants.

The cost of seedlings from average Dunemann beds, omitting overheads, is probably two or three times the cost of seedlings from productive mineral soil seedbeds but is equal to or less than the cost of seedlings from poorly stocked mineral seedbeds or beds where growth is slow. There is no scope for mechanisation in Dunemann beds.

#### SITE

The site requirements for Dunemann beds are far less demanding than for mineral soil seedbeds.

A site is required which is gently sloping or, if flat, has a freely drained soil. Frosty sites should be avoided. It should have a good supply of water and be convenient for supervision. It should also be free from perennial creeping grasses such as couch.

#### DUNEMANN FRAMES AND BEDS

Beds are made up inside frames which should be approximately 12 inches/*30 cm* deep, 6 feet/*2 m* wide and as long as is required. Paths between beds should be not less than 2 feet 6 inches/*0.75 m* wide, so that a barrow can be wheeled between the beds. The sides of the frames should be made of 1 inch/*2 cm* board; dunnage board or slabbing is quite suitable for this purpose. The sides should be supported on 2 inches x 2 inches/*5 x 5 cm* stakes driven well in.

#### DUNEMANN ROOTING MEDIUM

The frames should be filled to a depth of 11 to 12 inches/*30 cm* with spruce or other coniferous litter or litter from stands of mixed conifers and hardwoods.

It is important to consolidate the litter well by trampling while the frame is being filled.

Many rooting media have given good results; spruce litter has been most widely used but litter of other conifer species or mixed hardwoods and conifers has also been used successfully. At one large nursery, the lower half of the bed has been made up of bark peelings. This appreciably reduces the cost of the seedbed and where litter is in short supply, enables the best use to be made of what is available.

SOWING DUNEMANN BEDS

Seed may be sown direct onto the surface of the levelled and consolidated litter or it may be sown onto a ¼ inch layer of sieved beech mould. However, the use of beech mould has little effect on yield and adds appreciably to the expense of the technique.

The sowing density should be that recommended for broadcast conifer sowings on mineral soil seedbeds. Densities up to double this figure have been used but seedlings raised from sowings at double density tend to be spindly if germination is good.

Seed should be covered with $\frac{3}{16}$ to ¼ inch/*0.4 to 0.6 cm* layer of screened beech mould or sand free from silt and lime.

TENDING DUNEMANN BEDS

A regular supply of water is essential for high yields. Excessive watering may, however, encourage vigorous shoot growth and poor root development. Watering is one of the most expensive features of the Dunemann system, especially when water is applied by hand.

During the germination period and until germination is complete, water should be applied daily, preferably at the end of the day, at the rate of 1 gallon to 6 to 8 square yards/*1 litre per sq metre* of seedbed whenever there has been less than 0.08 inches/*2 mm* of rain during the preceding 24 hours. From the time germination is complete until mid-July, water should be applied at the rate of 1 gallon to 4 square yards/*1.5 litre per sq metre* every second day unless there has been 0.15 inch/*4 mm* of rain in the preceding 48 hours. From mid-July until the end of August, water should be applied at the rate of 1 gallon to 2 square yards/*2.5 litre per sq metre* at the end of each period of four rain free days. Thereafter no water need be applied.

There is no need to store water in the nursery for any period before applying it.

Shading is essential during germination. Lath screens made of 1 inch laths 1 inch apart, or their equivalent are suitable. Beds should remain shaded from the time of sowing until germination is complete, and during sunny or hot weather thereafter. Sudden exposure of seedbeds by removal of shading at the beginning of or during hot weather is likely to kill a proportion of the seedlings. A permanent overhead framework to carry the shades greatly facilitates all cultural operations but is only worth while where there are several beds together in a block. Otherwise, rolls of lath screens on posts and wire 12 to 15 inches above the surface of the bed are quite satisfactory.

Beds should be kept weed-free at all times.

Beds must be protected against birds. Where beds are shaded by permanent overhead screens, only the sides of outside edges of the nursery area need be protected. Polythene netting is suitable. Galvanised netting should not be used for permanent screening over beds: the zinc from the netting can accumulate in the litter sufficiently to kill plants.

No routine sprays are required against fungi. If fungal attacks develop, the appropriate treatments should, of course, be applied.

The responses to inorganic fertilisers have been small and are unlikely to cover the cost of the fertiliser.

### 7.64 Dazomet

Daxomet is a soil fumigant which has been found in experiments to give a stimulus to growth equal or nearly equal to that from formalin. It is available formulated as granules and can therefore be more easily applied than foımalin. In addition, in some nurseries on heavier textured soils, it has given a high degree of weed control in the first few months after seed germination.

For best results, dazomet granules should be spread in late summer or early autumn at the rate of 200-300 lb per acre/240–360 *kg per ha*. The ground should be rotovated after cultivation to a depth of 7–9 in/20 *cm*. At least three months must elapse between treatment and sowing.

Dazoınet is expensive (£100 per ac/£250 *per ha* in 1971) and should only be used extensively after small-scale trials in the nursery concerned have shown that a worthwhile response can be expected there.

FURTHER READING

ALDHOUS, J. R., 1962. A survey of Dunemann seedbeds in Great Britain. *Quarterly Journal of Forestry*, **56**, (3), 185–196.

ALDHOUS, J. R. and GLEDHILL, H., 1960. Temperatures at the soil surface. *Journal of the Forestry Commission*. **29**, 48–50.

BENZIAN, B., 1965. *Stunted growth and the effects of partial sterilization and related treatments.* (Chapter 8 in) Bulletin 37, Forestry Commission, London, 134–163.

BENZIAN, B., 1970. Nutrition of Young Conifers and Soil Fumigation in *Root Diseases and Soil-borne pathogens (Part Proceedings First International Congress of Plant Pathology, London* 1968, Ed. T. A. Tousson *et al.* University of California Press, 222-225.).

BRIND, J. E., 1965. *Studies on the effect of partial sterilization on the soil micropopulation.* (Supplementary paper in) Bulletin 37, Forestry Commission, London, 206–209.

EDWARDS, M. V., 1953. *Effects of partial soil sterilization with formalin on Sitka spruce and other conifer seedlings.* Forest Record No. 16, Forestry Commission, London.

FAULKNER, R., 1957. Experiments on seedbed compaction. *Report on Forest Research*, 1956, 113–123.

FAULKNER, R. and HOLMES, G. D., 1954. Placement of fertilisers. *Report on Forest Research*, 1953, 20.

FAULKNER, R., 1953. Notes on choosing a suitable conifer seedbed cover . . . *Scottish Forestry*, 7 (4), 121–124.

FAULKNER, R., 1957. Scottish experiments comparing chloropicrin with formalin as a partial soil sterilizer for conifer seedbeds. *Report on Forest Research*, 1957, 159-170.

LOW, A. J., 1971, Tubed Seedling Research and Development in Britain. *Forestry* 44(1), 27-41.

MINISTRY OF AGRICULTURE, 1954. *The calculation of irrigation need.* Technical Bulletin No. 4. Ministry of Agriculture, Fisheries and Food, London.

NEWTON, P. and GOULD, C. W., 1969. Germination room can bring controlled growing a step nearer. *Commercial Grower* 3809, 17-18.

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*See also*

APPENDIX VI: Formalin and Chloropicrin Trials, page 157.

# Chapter 8
# TRANSPLANTING AND UNDERCUTTING

The objects of transplanting or lining out are to provide greater space for young plants to develop, and to encourage the formation of a fibrous and compact root system, together with a higher ratio of root to shoot than would develop if seedlings were allowed to grow undisturbed in seedbeds.

Undercutting of seedlings *in situ* the seedbed is sometimes practised with similar objects in view. Undercutting is described in Section 8.8 following.

### 8.1 Spacing

Plants which are overcrowded in the lines or in the seedbeds become drawn and spindly and do not survive planting out as well as sturdy plants; adequate spacing is essential.

There are two factors in plant spacing, the size and the shape of the growing space. What little critical work has been done on transplants in forest nurseries shows, as one would expect, that the larger the space available per plant the bigger the plants produced. In a series of experiments, doubling the growing space from 12 to 24 square inches (*75 to 150 sq cm*) per plant increased the stem diameter of plants by 20 to 30 per cent but height by only 5 to 10 per cent. The shape of the growing space had little effect on plant size; nevertheless plants tended to be sturdier when planted with more space between plants in closer rows than when the same area was available per plant, but plants were closer in the row and the rows further apart.

In practice, mechanization of transplanting and subsequent operations are so greatly facilitated by a standard spacing between rows, that the only easy variation is of the distance between plants. Current practice is to space rows at 7, 8 or 9 inches with plants at 1½, 2 or 3 inches in the row/*17.5, 20 or 22.5 cm by 3.7, 5 or 7.5 cm.*

TABLE 27

RECOMMENDED GROWING AREA FOR TRANSPLANTS

| Average Height Expected at Lifting: inches | *cm* | Recommended Growing Area: sq in | *sq cm* |
|---|---|---|---|
| Less than 9 | *Less than 20* | 12 to 16 | *75 to 100* |
| 9 to 15 | *20 to 40* | 16 to 20 | *100 to 125* |
| 15 to 24 | *40 to 60* | 16 to 24 | *100 to 150* |
| Over 24 | *Over 60* | 20 to 32 | *125 to 200* |

The growing area available to plants should be determined by the size they are expected to reach when being lifted, as set out in Table 27.

Plants to be lifted after one growing season may be transplanted at a closer spacing than if they are expected to remain *in situ* for two growing seasons.

### 8.2 Plants for Transplanting

Seedlings are usually lifted from the seedbeds and transplanted, either at the end of their first or second growing season. Seedlings less than 1½ inches/*4 cm* tall are too small to be handled easily and quickly, and are usually discarded. If more than 40 per cent of all seedlings in a bed are less than 1½ inches/*4 cm* tall, the whole bed is better left to grow on for a second year. Nevertheless, special circumstances may justify planting such small plants, and experience has shown that many will survive and grow well. Small plants should not be transplanted until the risk of frost-lifting is past.

Often a proportion of seedlings in a bed are big enough to be handled easily and the remainder are too small, and a decision has to be taken whether to lift the seedbed and waste a proportion of the seedlings or to let the bed stand over, and possibly be

TABLE 28

NUMBER OF TRANSPLANTS PER UNIT AREA (EXCLUDING AREA OF ALLEYS) AT DIFFERENT SPACINGS

| Imperial Measure | | | | | Metric | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Spacing of Plants in Row | Spacing between rows: 6 in | 7 in. | 8 in | 9 in | Spacing of Plants in Row | Spacing between rows: 15 cm | 17.5 cm | 20 cm | 22.5 cm |
| | No. of Plants per 100 sq yd | | | | | No. of Plants per 100 sq m | | | |
| 1½ in | 14 400 | 12 340 | 10 800 | 9 600 | 3.75 cm | 17 800 | 15 250 | 13 300 | 11 850 |
| 2 in | 10 800 | 9 250 | 8 100 | 7 200 | 5 cm | 13 300 | 11 400 | 10 000 | 8 900 |
| 3 in | 7 200 | 6,170 | 5 400 | 4 800 | 7.5 cm | 8 900 | 7 600 | 6 650 | 5 900 |
| 4 in | 5 400 | 4 625 | 4 050 | 3 600 | 10 cm | 6 650 | 5 710 | 5 000 | 4 450 |

undercut, with the risk that plants may grow too big. The decision will be determined by such factors as the need for plants, whether the beds if left will make cultivation of adjoining land unduly difficult, and a prediction of the risk of disease—in particular Grey mould—spreading if the beds become too dense.

A third possibility is that the whole bed can be well loosened by undercutting so that the bigger plants can be picked out without excessive stripping of roots and the small ones left. This technique is most suited to beds where up to 30 per cent of the seedlings are clearly bigger than the rest, as may occur when seed germinates at two periods instead of germinating all at once. Often a proportion of the smaller seedlings get buried during the loosening or subsequent lifting.

In the same way as seedbeds can be picked over, so transplants which have been in lines for one or two years can be sorted at lifting into those big enough for the forest and those too short or too spindly for planting out. While there is no evidence that segregation of seedlings by size has any effect—seedling size being determined primarily by seed size and date of germination, repeated segregation of transplants can lead to separation of the inherently least vigorous stock as the residue held in the nursery. Normally, plants should be re-transplanted only once. At the end of the second period in the lines, stock should either be sent to the forest or should be burned. Exceptions to this rule should only be made for stock solely for amenity planting where larger than normal plants are required, and in the rare cases where late spring frost has caused extensive damage to shoots and there is a reasonable chance of recovery, given another year in the nursery.

### 8.21 Handling after Lifting

Roots of all plants to be transplanted must at all times be protected from drying by placing the plants in buckets or boxes lined with damp moss, or in polythene bags or by heeling the plants in. Plants in polythene bags must always be kept out of direct sunlight; see Chapter 9.

### 8.22 Grading of Seedlings in Preparation for Transplanting

Grading of usable seedlings into two or more size categories before lining out is an additional operation and one that often in the past has given little return for the labour involved. With most species, the range of seedling heights is small enough to have no effect on subsequent growth and usability at the end of the year in the lines. Grading is worthwhile only if there is such a big range in height of seedlings that the smaller plants need an extra year to grow to a usable size compared with larger plants. If grading is required, seedlings should normally be separated into two grades and no more.

### 8.3 Time of Transplanting

It is possible to lift plants at almost any time of the year and transplant them with success. However, much care has to be given to plants moved during the growing season to ensure good survival and in practice, the large majority of plants are lifted between the time when shoot growth ceases and winter buds form, and the time when the buds burst in the spring. During this dormant period, plants, ideally, should be lifted and transplanted at once. However, where any large number of plants have to be lifted at one time, they usually have to be stored safely until they can be transplanted. (Ch. 9). If it can be foreseen that planting must continue after the normal time of bud break, the plants involved should be lifted while still fully dormant and should be kept in a cold store until needed. (See Section 9.35).

Most plants can be lifted and transplanted most satisfactorily in late February and March in England and Wales, and March and early April in Scotland. By this time, the worst of the winter weather has usually passed, the soil is moist and the plants' roots have not yet started to grow. If done earlier, smaller seedlings run the risk of being heaved out of the soil by repeated freezing and thawing of the water in the surface layers of the soil—this risk is serious on all but the most sandy soils. Plate 16 illustrates frost-heaved seedlings shortly after transplanting. If transplanting is left late, plants run the risk of desiccation from the spells of dry weather which are common in early spring.

In any circumstances, the first species to be lined out should be larch, oak, beech and other hardwoods. Next the pines should be tackled followed by the spruces, Silver firs (*Abies* species); Lawson cypress, hemlock and Western red cedar. Douglas fir should always be left to last—indeed it is sometimes said that this species should be transplanted just as the buds break. The Silver firs should not be lined out late however; February/March is best for them. Corsican pine should be transplanted before the end of March; it has also done well when moved in the autumn.

Monterey pine, *Pinus radiata*, must not be lined out or planted in the forest in the winter. In the few experiments on date of planting, almost all plants of this species lined out in February or March have died while 90 to 100 per cent survival has followed planting in September and 60 to 80 per cent survival after planting in May. The reason for this difference is thought to be a matter of the soil temperature.

*Pinus radiata* can be transplanted without difficulty in many countries with Mediterranean or sub-tropical climates and would appear to require warm soil if newly transplanted stock is to grow well.

### 8.31 Summer Transplanting

In Scottish nurseries in particular, many species can be transplanted with great success in late June, July or August after the spring growth has hardened off, provided the soil at the time of transplanting is moist. This technique can only be used for seedlings in their second growing season, and for this reason it is not commonly practised in England. Also many English nurseries are on sandy soils in areas of relatively low rainfall and one cannot rely on moist soil for more than one week in two or three in July/ August. The plants resulting from mid-summer transplanting are quite as good and usually better than those left for two years and then lined out. Also the risk of late-season attack by *Botrytis* (Grey mould) in densely-stocked second year seedbeds is avoided.

Two pre-requisites, if summer lining out is to be put into effect, are firstly sufficient fallow land for the work to proceed without interfering with plans for early autumn transplanting or early throwing up of seedbeds, and secondly a labour force that is not already fully occupied by a weeding programme or other essential work.

## 8.4 Preparation of Ground

Ground for lining out must be free-working and not hard or compacted. In many nurseries, it is desirable to cultivate each day as much ground as can be filled with transplants that day. On very sandy soils, there is little harm in cultivating more than a day's ground at a time but on heavier soils any good tilth achieved by previous cultivations and winter weathering can be lost if the ground is ploughed or rotovated in preparation for transplanting and heavy or prolonged rain intervenes.

The sequence of operations preceding lining out depends on what the previous crop was, when it was removed, the condition of the soil and the weather and may include some or all of the following operations.

### 8.41 Late Autumn Ploughing

If ground has been fallow, or has carried a greencrop or for any reason has been cleared in the autumn, it should be ploughed in October or November and left rough. Any annual weeds will be buried and the ground will be in a state to benefit from weathering by frost and rain during the winter. Any dressing of ground mineral phosphate or magnesian limestone etc prescribed to correct soil deficiencies should be applied before this ploughing.

### 8.42 Ploughing-in Bulky organics

If hopwaste or other bulky organic manure is to be applied, this should be spread and ploughed or rotovated in a few weeks before lining out. Organics can be spread and ploughed in the autumn, but the longer the interval between spreading and transplanting, the more nutrients in the organic matter will be lost by breakdown and leaching before the plants can benefit from them.

### 8.43 Ploughing-in Crop Residues

If the ground has been under seedbeds or lines, it will normally need to be ploughed to level out paths between seedbeds or strips of transplants and to bury any remaining plants. This operation can be combined with either of the two preceding operations if convenient.

### 8.44 Lining-out Following Late Greencrop

Where a greencrop of rye grass has been sown late in the summer, this may be ploughed in as lining-out progresses and should not be ploughed in or cultivated beforehand.

### 8.45 Incorporation of Inorganics

In most circumstances, inorganic fertilisers should be spread not more than three weeks before lining-out. They do not need to be ploughed in and can be worked in as lining-out progresses, or they can be rotovated in shortly beforehand. Inorganics should not be applied as far ahead as the autumn if plants are to be lined out in the spring following.

On very sandy soils, Norway spruce and Grand, Noble and European Silver fir transplants lined out in late spring may be damaged by inorganic fertilisers, if prolonged dry conditions follow shortly after lining out. This risk is minimised by spreading the inorganic fertiliser no later than mid-March, even though the plants in question may not be lined out for several weeks; alternatively the regime outlined in Section 4.31 may be adopted.

### 8.46 Nutrient Regime for Transplants

This is fully discussed in Section 4.2 *et seq.* See also Section 4.57, page 31.

## 8.5 Technique of Lining-Out

There are several systems of work by which seedlings may be transplanted speedily and each has its particular merits and requirements. However, in all of them certain standards must be achieved.

*Position of Plant*

Plants must be set upright with roots radiating symmetrically downwards from the root collar. Plants set badly askew will straighten up but the base of the stem will remain curved and the young trees will be more difficult to plant in the forest. Similarly, shoots of plants set with all roots bent towards the horizontal in one direction will grow vertically but their roots will grow in the position they were put and if bent will thicken and harden in this shape and again will be difficult to plant. Such root systems are often described as "hockey stick roots". Straight plants with good roots can be grown provided the trench, notch or slit made is vertical and not sloping and is wide and deep enough to accommodate the roots of the plants being handled. The collar should be at or just below the soil surface. Good supervision is essential if this standard is to be achieved.

*Prevention of Drying of the Roots*

Roots of seedling forest trees will die if allowed to dry and they can do this in a very short time on a warm breezy spring day. Once lifted, plants must therefore be kept in boxes, buckets, polythene bags or hampers etc out of the sun and wind until required. Plants must not be left out of the ground in lining-out boards or in open bags for a second longer than is necessary.

Plant roots are sometimes dipped in water or in a slurry of soil and water but though this practice can be traced back to ancient Greek times, there is no clear evidence that the proportion of plants surviving is increased.

Materials, such as alginates, which make water more viscous are currently on the market. Roots dipped in viscous or "thickened" water retain more of it on roots than if plain water had been used. However, this and other forms of dipping are only likely to be effective if conditions are otherwise unsuitable for lining out, i.e. dry soil or severely drying winds.

Plants must be protected from the wind while being placed in the lining-out boards. This is commonly achieved by screens of hessian or polythene on wooden or tubular steel frames. The frames are 6 feet/*1.8 m* high and are shaped to give protection on three sides.

*Firmness in the Ground*

Following transplanting, plants must be firm enough in the ground that they can not be uprooted by a gentle, steady pull. Plants which are loose take longer to become established and are also more likely to suffer in dry weather through inadequate contact between roots and soil.

If simazine is used to control weeds and the soil is loose, the simazine can be washed down by rain into the rooting zone of the crop plants rather than the top ½ to 1 inch/*1.5 to 2.5 cm* in which weeds germinate, thereby increasing the risk both of crop damage and of inadequate weed control.

### 8.51 Hand Laying

The simplest system requires no more than a garden line and a dibble with which to make a hole and put in seedlings one by one. Alternatively, a "V" shaped trench 5 to 6 inches/*13 to 15 cm* deep may be dug with a spade, one face of the trench being vertical. Plants are then placed in position by hand against the vertical face. Each plant is secured in place individually by pressing a handful of soil against the roots to hold them to the trench until a three or four foot length of trench has been set with plants when the trench is filled in, and the ground to the side consolidated by treading and levelled.

Both these methods have been used in the past but have been superseded by methods which are less back-breaking. However, with skilled men, these old-fashioned methods were little slower than those currently practised.

### 8.52 Lining-out, Using Boards. Plate 10.

In the board system, plants are laid side by side onto a board until it is full, when a second board (or lid) is secured so that the plants are gripped between the two boards and can then be moved to the trench. The two parts may be hinged together or free. The two types of boards most widely used are the 10 ft ("Ben Reid") hinged board and the 6 ft 4 inch ("Paterson") unhinged board (approx. *3 m* and *2 m* long respectively).

### 8.53 Lining-out, Using the Short ("Paterson") Lining-out Board and Strip Method of Working Plate 11.

For this system teams of two men, or a man and a girl, are required, each team working at its own rate independently of others. One man digs while the other member of the team fills the boards.

The equipment required consists of:

(a) One filling frame and screen; stamping or distance board (6 or 8 inches by 1 inch by 6ft 4 inches) edged with metal; (*metric equivalents: 15 or 20 cm by 2.5 cm by 2 m*).

(b) One reversible notched distance piece to fit the filling frame, with notches on one edge 2 inches/*5 cm* apart and 1½ inches/*3.75 cm* apart on the other.

(*c*) Two or three plain lining-out boards 6 ft 4 inches/*2 m* long. The boards are not hinged but separate into two parts which are held together or released by swivelling pegs. The boards are lined with strips of soft rubber to help grip plants without injury.

The method of work using short boards is:

A guide line is laid down at right angles to the direction of the transplant lines along one edge of the strip.

The stamping board is then placed on the ground with the long side at right angles to the guide line but touching it at one end. The soil close to the leading edge of the board is trodden along the boards length. This firms the ground sufficiently for the vertical face of the trench to be cut, without crumbling. The trench is then cut by spade using the leading edge of the distance board (the edge with the metal strip attached) instead of a line; the worker retains one foot on the board to keep it in position.

The distance board is then removed and the filled lining-out board is placed in position. (Since the distance piece and the lining-out board are both 6 ft 4 inches/*2 m* long, the trench is of just sufficient length to receive the latter).

Soil is then returned to the trench, slightly banked up against the lining-out board, trodden, and roughly levelled using a spade.

The board is then placed with one end against the line and the wooden edge against the just-planted trees, when the sequence of operations is repeated until the end of the strip is reached.

The strip method of working is best suited to small nurseries, or nurseries on heavy soil. Cultivation by hand-tools can be done from the paths between strips, but it is difficult to use mechanical equipment.

**8.54 Transplanting into Long Lines—"Ben Reid" Boards.** Plate 10.

Following the advent of weedkilling sprays and of hoes and springtines mounted on a tractor tool-bar, it has become common practice to line out in beds of five or six long lines, each bed being separated by an alley wide enough to allow a tractor tyre to pass without damage to trees. Long lines can be planted solely by hand or with the assistance of lining-out ploughs or transplanting machines.

Long lines planted by hand are most easily worked with between three and six pairs of workers, each pair completing a length of line corresponding to two or three board lengths. The equipment used is almost the same as for strip working, a ten-foot-long "Ben Reid" board being substituted for the "Paterson" board, though this latter board can also be used. The older design of "Ben Reid" board carried a notched strip of wood, the notches being at the desired spacing of plants. More recently made boards have been fitted with rubber strips similar to those in the "Paterson" board instead of the notched strip. The method of work is similar to that of the strip method except that a garden line or wire is used to mark the position of the first row of plants in a bed. Each pair of workers keeps pace with the others so that the whole of the working section is completed one row at a time. After the first row which is marked out by line, the location of the second and subsequent rows in a bed is determined by moving the garden line or more commonly by use of a spacing board. Properly supervised, transplanting by this method gives evenly spaced rows which can be cultivated or sprayed with ease. By careful selection of men able to work at similar rates, teams can be made up in which all will work at much the same speed to complete the whole or a substantial part of a section. If a faster and slower team share a section, the slower team must line up with the rows already put in by the faster team.

**8.55 Lining-out Ploughs**

Several types of plough have been used to eliminate the heavy digging work of lining-out. Two of these, the "Ledmore" and the "York" are in general use. Both of them open up a trench and at the same time fill in, consolidate and level the trench previously opened. Both require a forester who will go to the trouble of mastering the mechanical adjustments that have to be made to get the machine working at its best and of training and organising his labour force to exploit their full potential. Using a lining-out plough, fewer skilled men are required and unskilled staff can often line out as many plants per day as could be achieved by skilled men by hand methods, and much less hard manual work is required.

*Ledmore Plough* (Rose, 1962). Fig. 3 and Plate 12.

The plough is designed to fill and level one lining-out trench and to cut and prepare the next simultaneously. In operation, it fills a trench in two stages, first turning and compacting top soil against the seedling roots and then turning in and levelling the bulk of the soil.

The first versions were trailed but subsequent ploughs have been built for mounting on the three-point linkage of a tractor and measure only six feet long by four feet wide. The plough, once tested and set, largely controls its own depth of working.

Within reason, varying soil conditions do not affect working except where there are large buried stones, and the plough will operate on gentle slopes. Working with a well-organised squad and capable supervision, between 8 and 12 000 seedlings per

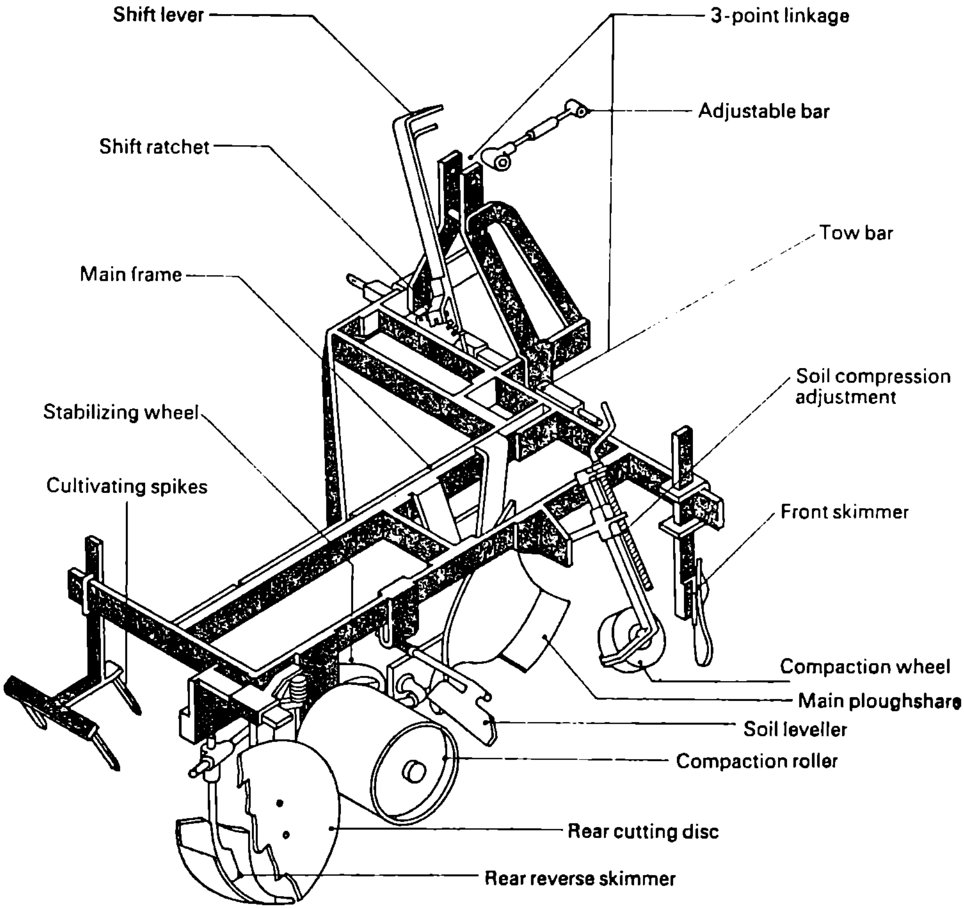


**Fig. 3. Ledmore lining out plough for transplanting.**

man-day can be lined out by a squad. This rate of work is calculated including the tractor driver and supervisor as members of the squad. The number of plants depends to some extent on the spacing of plants in the row; the closer the spacing, the more are lined out in a day.

In the Forestry Commission's nursery at Ledmore, Perthshire, this plough was used regularly for fifteen years and for shorter periods in other nurseries. The quality of plant produced is as good as by hand-lining, and the percentage survival of plough-lined seedlings is at least as high as that of hand-lined seedlings. The plough may be fitted with a fertiliser distributor if required. By using the appropriate linkages, the plough can be mounted on different makes of tractors. The best results are obtained when the tractor is fitted with a low reduction gear box but tractors without reduction boxes can be used with satisfactory results.

The plough can be used in any length of nursery section; at Ledmore a section 360 feet/*approx. 110 m* long, i.e. the length of 36 ten foot/*three metre* lining-out boards was found convenient. On sloping sections it is best for the plough to be worked uphill rather than down or across the slope. The plough works up the section, filling one trench and cutting the next. At the top of the section the plough is raised and the tractor returns to the bottom of the section ready to start the next run. The tractor is lined-up, the plough lowered and the next working run started, and so on. Once the plough has passed, the boards are lifted from the filled trench and full boards are placed along the new edge. If nuts and bolts have been used to secure hinges between the two parts of the boards, these should be reversed and countersunk to allow the compaction roller to run close beside the board without snagging.

Lines planted using the Ledmore plough are nine inches/*22 cm* apart. Lines can be arranged to fill a section completely but usually one row in six is left unplanted; five runs of the plough complete one strip or bed of five lines 36 inches/*90 cm* wide, with a space of 18 inches/*45 cm* as an alley between adjacent strips.

Fifteen men are required for the plough to be used to best advantage and the success of the whole operation depends, partly on a squad in which every member knows his part and can do it quickly and accurately, and partly on good organisation to ensure a steady supply of plants and the minimum of unnecessary walking from shelter to lines.

*York Plough* (Sharp, 1960). Plate 13.

The machine does much the same job as the Ledmore plough and requires similar organisation but differs in several ways.

Instead of filling and cutting to one side of the line of working and moving over for each line, the York plough straddles a bed or strip of ground and runs over the same tracks six times until all lines are filled. The plough itself is moved across relative to the tractor to cut consecutive lines. The rows are eight inches/*20 cm* apart.

Where conditions are wet or difficult, half-tracks fitted to the tractor prevent the risk of bogging down. The alleys between beds or strips need to be twenty-four inches/*60 cm* wide if half-tracks are used. Otherwise alleys should be eighteen inches/*45 cm* wide.

Ground for lining-out using the York plough needs to have been cultivated to a depth of eight inches/*20 cm* and to have been firmed subsequently by running over with the tractor.

The standard long board of ten feet is used with some important modifications. These include the use of bolted-on lengths of 1½ inch/*3.75 cm* wide hoop iron to replace the steel pins in common use. The hoop iron rests against the back of the open trench and prevents the board being misaligned on to the trench. Rubber grips made from bicycle tyres are used instead of the two-inch spacing board or notched bottom board, and do away with the need for turn clips or buttons on the hinged flap. Specially short hinges are used to prevent fouling of the underside of the tractor.

The alignment and straightness of rows is ensured by use of a garden line to which the tractor driver works for the first row of plants in each strip of six rows, the garden line being moved at any convenient time after the first row of plants has been completed.

A squad of 12 to 14 people is required, of whom 10 or 12 can be unskilled women or youths, together with a tractor driver and ganger. The output is similar to that with the Ledmore plough.

**8.56 Transplanting Machines.** Plates 14 and 15.

Several types of transplanting machines have been tried in various forest nurseries, and are becoming more generally adopted.

The more successful types are based on the "Accord", "Holland" or "Super-prefer" transplanter units. All units have a planting wheel into which plants are placed like spokes with the roots projecting beyond the margin of the wheel (Plate 15). Plants are gripped in place on the wheel either by soft rubber or by a spring-loaded catch, and are held firmly until in position in the ground when they are released. A narrow parallel-sided trench is opened by a share and closed by compacting wheels immediately the plants are released.

The advantages of transplanting machines are that they eliminate both the hard manual work of digging trenches and the need to fill boards. They are also capable of very high rates of work. But:

(*a*) transplanting machines travel very slowly and have to be drawn by a tractor fitted with a low reduction gear box.

(*b*) where two planting units are operated, a third man is often kept hanging around doing very little, while if five or six units are coupled up, a bigger tractor is required to pull it than is normally available in forest nurseries.

(*c*) while the workers avoid the bulk of the physical labour of carrying and digging, they have little scope to move and can get very cold, even though screens may be fitted to give some protection from the wind. Another disadvantage is that neither the "Super-prefer" nor the "Holland" units plant at a spacing much below 2½ inches/*6 cm* in the row or the rows closer than eight inches/*20 cm*. The "Accord" can plant down to 7 in/*17.5 cm* between rows and is not limited in the spacing of plants along the row.

Plants raised following mechanical transplanting have been satisfactory except where roots have dragged back on the share on entering the ground, when plants with a "hockey-stick" root system have developed. This trouble may be reduced by enlarging the share, and by ensuring that any unduly long roots are cut off.

### 8.6 Weed Control in Transplant Lines

Transplants will be able to make the best use of nutrients and soil moisture if competition from weeds is eliminated. Heathland nurseries, starting clean, can and should be kept in this condition to the benefit of the crops and the nursery budget. If weeds are prevalent, herbicides should be used, full details of which are given in Chapter 10. If for any reason these cannot be used, the same freedom from weed competition can be achieved by regular very frequent light surface cultivations, using tractor-mounted tines or hand tools like the hoe, supplemented by hand weeding of weeds growing between plants in the lines.

It is unthrifty and, in the long term disastrous, to allow the number of weeds to build up towards the end of the year. While such weeds will undoubtedly be buried when the ground is ploughed following clearance, and while it is also true that the transplants themselves will suffer little, nevertheless many weeds will release viable seeds, especially the annual meadow grass, *Poa annua*. Such seeds will germinate in subsequent years, aggravating the weeding problem, possibly at a time when it cannot be dealt with before plants suffer.

### 8.7 Pest Control in Transplant Lines

Most species require no attention other than weeding in the transplant lines. However, the following troubles may be encountered and should be dealt with as recommended in Chapter 11, page 107: Leafcast (*Meria laricis*) on larch; Keithia disease (*Didymascella thujina*) on Western red cedar; mildew on oak; aphis on beech; spinning mite on spruce.

Plants may be damaged by late spring frosts but damage should seldom be serious if the nursery is properly sited away from frost hollows and low-lying situations; no routine protective measures are recommended unless there is positive evidence of incipient trouble.

### 8.8 Undercutting, Root-Pruning and Wrenching

The term "undercutting" (synonym "root-pruning") means that the roots of plants are severed below the surface of the soil by a blade passing horizontally along under the seedbed at a regulated depth. (See also Section 8.88 Wrenching). Plants may be undercut at any time once their roots have penetrated to a depth of 8 to 10 inches/*20 to 25 cm* in the soil.

Undercutting has a dual role in nursery management.

Undercutting can be used "positively" as part of a nursery policy of producing stock fit for planting without transplanting. If this is the aim, seedbeds have to be sown at a lower than normal density, specially for undercutting in the late spring or early summer of their second growing season. Alternatively, undercutting can be used as a "salvage" technique, being used to check growth of plants, for example to keep the size of second year seedlings within bounds if for any reason they have to stand over and are otherwise expected to grow too big.

A third reason for undercutting in this country is for the purpose of stimulating the growth of more fibrous roots in plants which, even without undercutting, would have been quite suitable for lining-out or for planting in the forest. This undercutting is done in late summer and autumn on any stock whether to be lifted and despatched in the following winter or spring, or to be undercut in the following season.

### 8.81 Undercut Seedlings in the Forest

Undercut seedlings have been planted, have become established and have grown as well as transplants on a wide range of sites and in many planting seasons. Only undercut seedlings of Corsican pine have failed to do as well as transplants both in experiments and in several areas in general practice. However, undercut seedlings have not been tested against transplants in the most rigorous conditions and are likely to fare worse than transplants in any circumstances where the ratio of root to shoot is critical.

### 8.82 Effect of Undercutting

Whatever the age and type of plant, undercutting during the growing season cuts or breaks roots, stimulating the growth of new roots to replace those lost; undercutting also checks shoot growth. The effect on the balance of shoot and root depends on when in the year plants are undercut. Thus, undercutting late in the growing season or while they are dormant has little effect on shoot growth that year, though 'lammas' growth may be stopped. The biggest reduction in shoot growth follows undercutting early in the growing season.

Atterson (1964) reporting a series of about forty experiments in Great Britain, found that the differences in height between seedlings, undercut seedlings and transplants of the same age were not great—differences between transplants and undisturbed seedlings average 20 per cent—but that transplanting resulted in increases in average recoverable root weight of 60 per cent more than the root weight of undisturbed seedlings. Both in shoot and root growth, undercut plants in these investigations were intermediate between seedlings and transplants, i.e. undercutting checked shoot growth and stimulated root growth but to a lesser extent than transplanting, but undercut seedlings more closely resembled undisturbed seedlings than transplants.

In these experiments, plants were undercut once only while in the nursery. In practice in several nurseries, plants have been undercut several times during the season and this has stimulated the production of more fibrous root than has been produced by a single cut. If repeated undercutting is to be practised, each cut should be slightly deeper than the preceding one.

Undercutting in early autumn is practised in Denmark and New Zealand and elsewhere, on stock to be lifted later that winter. Undercutting at this time has no effect on shoot growth but stimulates root fibre development.

**8.83 Depth of Undercutting**

The most suitable depth to undercut seedlings is between three and four inches/*8 to 10 cm.* If plants are cut at about two inches/*5 cm* depth, they are liable to suffer acutely and die if prolonged drought follows undercutting; also the risk of the blade coming to the seedbed surface and cutting seedlings off at ground level is increased. If the cut is made below four inches/*10 cm*, only a very little extra root growth is stimulated by the undercutting.

Transplants should be undercut at between four and six inches/*10 and 15 cm.*

**8.84 Side-Cutting**

One way in which the pines and to a lesser extent larches respond to undercutting is by developing excessively long lateral roots. These can be checked on drill-sown seedbeds or in transplant lines by using discs, vertical blades or spades to cut vertically down half way between the rows of plants. This operation may be carried out three or four weeks after undercutting.

**8.85 Sowing Density**

Substantial reductions have to be made in the density of seed sown for the production of undercut plants. See Section 7.35.

**8.86 Economics of Undercutting**

The main attraction of undercutting instead of transplanting is the saving in transplanting costs and the corresponding demand on labour, and the avoidance of losses following transplanting. On the debit side has to be placed the cost of maintaining the greater area of seedbeds sown. In practice, the advantage is by no means always in favour of undercutting; any reduction in germination of seed raises the cost of seedlings, especially in nurseries where weeds are well-established, as the cost of hand weeding in the first year is substantial. It is this cost particularly which has in many instances turned the balance against undercutting. On the other hand in clean heathland nurseries where germination is good and regular, and also in nurseries where transplanting losses are high, undercut seedlings may be between 30 and 50 per cent cheaper to produce than transplants.

**8.87 Undercutting Equipment**

In Great Britain, undercutting has been done almost entirely by tractor-mounted blades. The use of wires for undercutting plants raised in boarded beds or in tubes prevalent in many countries with warmer climates has found no place in British practice.

The blades most commonly used are illustrated in Plates 19 to 21. Other locally made variants on these have also given good service.

Plate 18 illustrates the Gunn lifting bar. This bar has detachable tines which should be fitted when the bar is used for lifting but should be removed before undercutting. Most locally made undercutters are on the same principle of a straight bar with a sharpened leading edge, but the bar is often mounted at an angle of 60° to 80° to the line of travel whereas the Gunn lifter is set at 90° to the line of travel.

Undercutters have also been produced (Plate 21) in which the straight blade reciprocates while passing through the soil. The machine illustrated was designed for nurseries in south-east England to cut through dead bracken roots which otherwise caused a build up in front of undercutter blades. A machine of similar design had previously been made in north-east Scotland.

The blades of both the "Blair Atholl" and the "Ledmore" undercutters (Plates 19 and 20) are set at an angle of approximately 45° to the line of travel in order to get a better cut of roots. Also both have a means of depth control independent of the tractor. The Blair Athol undercutter has a forward-pointing "V" blade supported at the centre of the "V" and at the ends of uprights mounted on a sledge. These uprights can be adjusted to allow the blade to cut at any given depth in relation to the alleys in which the sledge runs. The Ledmore undercutter has two substantial independent blades pointing backwards and just meeting but not connected. Each blade is supported from one end only. Their depth is adjustable in relation to wheels which, again, run in the alleys between seedbeds.

While all the undercutters have some depth control, if only that determined by the hydraulic lift on the tractor, all are relative to the alley and not to the seedbed surface. For regular undercutting, it is therefore important that the alley level is consistently the same distance below the surface of the seedbed.

Two other points should be watched while undercutting. Firstly, twigs, roots, weeds and rubbish can accumulate in front of any of the vertical supports for undercutting blades. This accumulation can devastate strips down a seedbed unless quickly cleared, and it is worthwhile having a man to follow the tractor watching for and clearing blockages of this sort and making any fine adjustments to the depth of the undercutter.

Secondly, all leading edges passing through the soil should be kept sharp; this is easier if the blades are made of spring steel. Sharp edges will not only reduce the traction required to pull the undercutter and minimise the risk of wheel-spin but will also reduce the risk of build up of vegetable debris in front of any blade or support.

**8.88 Hand Methods of Undercutting; Wrenching**

Transplants or drill-sown seedlings may be "wrenched" or undercut by spade. The spade is inserted to its full depth at an angle of about 45° about four inches/*10 cm* from the base of plant and the plant lifted slightly. This operation is usually performed as a salvage operation to prevent plants getting too big rather than to avoid transplanting as such.

**8.89 Manuring for Undercut Plants**

No critical work at all has been done on the best nutrient regime for undercut plants. The best course is to observe the condition and appearance of the plants themselves regularly during the growing season. Needle size and colour are sensitive indications of the well-being of the majority of species; if the plants in the second year show symptoms of any deficiency, the appropriate nutrient should be applied as a top dressing. If they lack vigour, light top dressings of nitrogen ("Nitro-chalk"or sulphate of ammonia) should be applied.

**8.9 Special Techniques for Transplants**

**8.91 Nisula system of Transplant Production**

In Scandinavia, a technique has been developed whereby seedlings are transplanted into a thin layer of peat and then rolled up in polythene strip. These operations can be fully mechanised in factory-like conditions, and plants in rolls grown wherever convenient. The whole process can therefore be independent of soil type.

Rolls are prepared, starting with thin (100 gauge) polythene sheet, 12 inches wide and 33 feet long/*30 cm × 10 m*. Milled sphagnum peat is placed in bands *5* inches wide and ⅝ inch deep/*12 × 1.5 cm* across the polythene and seedling positioned at each end of the peat band, roots inward and root collar about ¼ inch/*0.5 cm* inside the edge of the polythene. Bands are spaced at 8 inches/*20 cm* between centres until 100 plants have been placed in position. The polythene is rolled up as peat and plants are placed in position and the end secured to the roll by glue. The roll is then cut in half to produce two rolls, 6 inches/*15 cm* high and each containing 50 plants. Rolls are about 12 inches/*30 cm* in diameter.

In British trials, 1½ ounces of "Enmag" and 1½-2 ounces of ground lime have been mixed with each cubic foot of peat/*1.5 and 1.5-2.0 kg per cu m respectively*. Rolls have been kept outside in beds and inspected daily and watered when the peat appeared to be drying. Once in June, July and August a solution containing 1½ ounces of ammonium nitrate per gallon of water was applied at the rate of one gallon per two square yards of bed surface area/*25 g ammonium nitrate in 3 litres water per sq m*. Plants do not need to be shaded. By mid-June, the roots of all species have grown sufficiently to hold the peat strip round the roots. Thus, roll transplants can be planted from late June through to early spring following, as ball-rooted plants. Plants have so far been separated from their rolls at the planting site.

Growth of the common species was good, and root development excellent. While plants are crowded more densely in rolls than in open ground and as a result more spindly than normal, survival and early growth in the forest has been quite as good as bare-rooted plants.

FURTHER READING

ATTERSON, J., 1964. Survival and growth of undercut seedlings in the nursery and forest. *Report on Forest Research*, 1963, 147–156.

EDWARDS, M. V. and HOLMES, G. D., 1951. Effect of height and diameter on growth and survival of planted-out seedlings. *Report on Forest Research*, 1950, 22–23.

FAULKNER, R., 1953. Early observations on the root development of one-year-old Corsican pine seedlings following root pruning. *Scottish Forestry*, Vol. 7 (1), 23–26.

FAULKNER, R., 1958. Summer, autumn or spring lining out. *Scottish Forestry*, Vol.**12**, 127–134.

ROSE, A., 1962. Ledmore mounted lining-out plough, Mark IV. *Journal of the Forestry Commission*, No.**31**, 90–97.

SHARP, G. A., 1960. Sharp's lining-out plough. *Journal of the Forestry Commission*, No. **29**, 50–53.

# Chapter 9
# LIFTING, STORAGE AND DELIVERY OF PLANTS

Plants are vulnerable, especially to damage by drying-out or heating-up, while they are being lifted and despatched to a planting site or to another nursery. Nurserymen are not usually credited for plants until they are safely delivered to their destination; unless great care is taken during this last stage, the work of two, three or even four seasons will be forfeit for no return.

Care during lifting, storage and delivery must be directed to:

(*a*) retain the maximum amount of short fibrous root, avoiding stripping the bark off the roots, and breaking of roots or tops or other mechanical damage.

(*b*) stop plants from drying out, in particular to prevent consequent dying of roots.

(*c*) avoid heating-up of plants while in store or in transit. This heat is generated by respiration of bacteria and micro-organisms on the plant surfaces. If plants are so tightly packed that air cannot circulate, the heat cannot escape, the plants warm, respiration increases in the warmer conditions, and in so doing generates more heat. This vicious circle may go on until conditions are so hot that plants are killed. The same process occurs in a freshly made compost heap. The process can be interrupted at any time by improved ventilation but if heating has gone so far that plants are warm to the touch, most plants will at least have been weakened and have less chance of surviving.

## 9.1 Lifting

When lifting, the more fine fibre and short branched roots plus root tips that are retained, the better the chances of good survival and growth in the nursery lines or in the forest. Roots exceeding six or seven inches/*15 to 18 cm* in length are an embarrassment, and should be cut off; otherwise they will drag on the sides and bottom of the lining-out trench or in the planting notch and cause the whole root system to become misshapen and bent. In seedlings, this shape will persist so that at the end of the year, the transplants will be found to have "walking-stick" or "hockey-stick" roots. In the forest, twisted roots may persist for many years and may even lead to premature windblow.

### 9.11 Hand-working

When lifting by hand the beds should always be worked from an outside edge. A garden fork or spade should be inserted vertically to the full depth of the blade and the handle pressed down until it is at an angle of 45°from vertical. This movement is repeated until the soil is loose, when the tops of as many plants in the loosened ground as can be grasped comfortably should be lifted gently, shaking the soil from the roots while lifting.

### 9.12 Mechanical Aids to Lifting. Plate 18.

Several machines designed to loosen plants in the soil and lift them are available, e.g. "Fobro" (made in Switzerland) and the "Plantlift" (Dutch made). The National Institute of Agricultural Engineering has also produced a "Universal Vegetable Lifter" that can be used for some types of forest planting stock. None of these is currently in general use; instead, reliance is generally placed on cheaper simpler tools.

The most widely used aids to lifting are specially designed lifting bars and some undercutting blades, all of which loosen soil and so assist lifting. The most suitable bars are those on which the angle can be adjusted to lift the soil to a greater or lesser extent; they are set so that the soil is loosened sufficiently to free the roots but not so much that the soil is turned over and plants buried. The setting of the blade may have to be adjusted from time to time in a nursery in relation to workability of the soil. Once the soil has been loosened, plants are lifted out by hand. The soil may settle back round the roots if more than a couple of days separate mechanical loosening and lifting.

Double-row potato lifters have been adapted successfully for loosening plants both in seedbeds and transplant lines. The conveyor belts normally need to be set with little or no agitation, depending on soil type, so that after the machine has passed, plants remain upright in the soil but thoroughly loosened. They can then readily be picked up by hand without stripping the roots, sufficient soil remaining to protect the roots from drying if lifting does not follow immediately. If the belt is agitated too much, all the soil falls away and plants are left on the soil surface higgledy-piggledy with their roots exposed; the machine works so fast that it becomes impossible for nursery workers to pick up such plants in a reasonably short time, unless an exceptionally large squad can be mustered.

If a plant lifter is available but the ground is filled with lines of transplants, without a space after every fifth or sixth row for tractor tyres to pass, two rows in every seven or eight can be lifted by hand so that the remainder may be loosened by the plant lifter. In this way the greatest stocking of sections can be achieved without losing much of the advantage of mechanical lifting.

### 9.2 Grading and Counting

On lifting, plants must be separated into those of a quality acceptable for transplanting in lines, or planting in the forest, and rejects, i.e. all diseased plants together with those that are too spindly, have inadequate roots, multiple leaders or have been damaged during lifting. Rejects, or culls, should be destroyed. See Section 1.5 for standards of quality.

The acceptable plants may be further graded by height into two or more size classes.

In commercial nurseries, plants are usually sold and priced by height grades and careful grading is essential to obtain the best commercial advantage. In estate nurseries raising plants for the use of the same estate, grading of planting stock is necessary only if plants are so variable in size that some will need an additional year's weeding in the forest compared with the bigger plants. The practice of loosening beds and removing plants in the various grades only as required is widespread, but the first plants removed are likely to lose more roots in the process than if all the plants are lifted together.

The older practice has been to count and grade as lifting proceeds and is appropriate to hand lifting and individual working. In larger nurseries however, plants may be lifted unsorted into boxes and taken to a grading shed for counting and packing. In the largest, most fully mechanised nurseries, plants may be put onto a short conveyor belt, on either side of which women remove plants of selected grades, leaving only the culls.

Grading and packing under cover has the advantage that work may proceed during wet weather and in the early mornings when the ground is hard following overnight frosts. Provided the shed is well lit, working conditions under cover will usually be better than outside. Lifting must be speedy and reliable if the graders are not to be held up and time lost, and attention must be paid to the safe storage of plants after lifting while awaiting grading.

After grading and counting, plants may be tied in bundles with binder twine or light string, or, if polythene bags are being used, sufficient plants may be put in the bag to fill it comfortably and keep the plants in order without being tied in bundles.

### 9.3 Storage

Ideally, plants should be lifted while dormant, packed and immediately despatched to the planting site without any period in store. Unfortunately, this is seldom practicable for any but small lots of plants. Often, sufficient plants have to be lifted to fill a lorry or railway waggon, and the first plants lifted have to be stored until the others are lifted.

It may even be preferable to keep plants in a cold store or ventilated shed until required rather than leave them in the ground, when:

(*a*) so large a number of orders for plants is expected that they cannot all be met without some delay, unless plants can be lifted and stored before the orders arrive, or

(*b*) plants are going to be planted out in the forest or lined out in transplant lines so late in the growing season that if left they will have started to grow before they can be moved, or

(*c*) surplus seedlings are to be stored until mid-summer for lining-out.

In the last two situations, access to a cold-store is essential.

#### 9.31 Storage Methods

While awaiting despatch, plants once lifted may be stored out of doors in a "heel" or "sheugh", in a well ventilated store in boxes lined with damp moss or in polythene bags, or in a cold-store in polythene bags.

One important advantage of indoor storage is that plants may be taken from the store and despatched more speedily than if heeled in or if they had been left unlifted in the ground.

#### 9.32 Outdoor Storage

This is the traditional method of storing plants though it has been replaced largely by indoor storage. Plants may be "heeled in" or "sheughed", loose or in counted bundles. In either case, a trench with a sloping back is dug and the plants laid in it thinly so that their roots are completely in the trench and most of the tops are out. All or part of the trench may be filled with plants at one time. As soon as the plants are in, loose soil thrown out from the trench is put back over the roots and lightly firmed down. There must never be so many plants in any part of the trench that the root system of plants, whether loose or bundled are out of contact with the soil. If this occurs, such plants will start to dry out and are the less likely to survive planting the more they dry.

If plants have been counted before being heeled in but have not been bundled, sticks can be used to mark every hundred plants.

If it is anticipated that orders for plants will come in very frosty weather, straw should be spread thickly over the plants to prevent soil being frozen to them.

### 9.33 Storage in Polythene Bags

Plants may be stored safely for long periods in polythene bags provided the recommendations below are strictly observed. The polythene ensures that the plants do not dry out and that they reach the planting site in as moist a condition as when they were lifted. In addition, plants stored in polythene bags have been found extremely convenient to handle.

There have been no cases of *Botrytis* (Grey mould) spreading from infected to other plants inside polythene bags. Fungi that are normally saprophytic in the soil, have, however, spread as a white mould starting from the roots or near the root collar. Plants have been attacked when they have been in store for too long or when they were packed in too wet a condition or where soil has been allowed to come into contact with foliage. Plants in bags in which such white mould has started to show itself should be removed from the bag as soon as possible and should be lined out or heeled-in, in a shady spot.

Where large consignments of plants are to be despatched, counting and checking is simplified if all the bags have the same number of plants of any given species in them.

Usually, moisture condenses inside polythene bags so that it is difficult to see which species is inside the bag. In large nurseries where large numbers of bags are in store, any subsequent inconvenience can be averted either by writing with marking ink on the outside of the bags using a felt pen, or by using different coloured labels for particular species.

*Summary of Recommendations for the Use of Polythene Bags for the Movement of Nursery Stock*

The following fourteen points (*a*) to (*n*) should be observed.

(*a*) Plants should be lifted and placed in polythene bags as quickly as possible. If there is likely to be any delay, roots must be prevented from drying out by covering with damp hessian, moss, etc.

(*b*) The surface of needles or leaves of plants should be dry when being put into polythene bags.

Plants lifted and packed with wet foliage are liable to rot.

Packing with dry foliage is especially important for Douglas fir, Western hemlock, Western red cedar and Lawson cypress.

(*c*) Plants should be packed with shoots in the same direction.

(*d*) Plants must not be packed in layers with the lower roots of one layer pressing on the tips of shoots of plants in a lower layer.

It may be found more convenient to tie plants into bundles before packing, especially where many small plants are being packed in a large bag. Generally, however, it is preferable not to tie into bundles.

(*e*) Plants must not be packed too tightly.

(*f*) Plants must be fully enclosed inside the bags.

(*g*) If bags are to be used once only and are not returnable, a light (200 or 250 gauge) bag may be used. For repeated use, a heavy (500 gauge) bag is more satisfactory.

(*h*) Check for punctures or tears, which seriously diminish the efficiency of bags.

One or two small punctures will have little effect on plants stored for short periods. However, plants to be stored for more than 3-4 weeks should be put into undamaged bags. All badly punctured or torn bags should be destroyed.

(*i*) Bags should be tied at the neck with *string*.

Adhesive or cellulose tape does not stick to damp or dirty bags, while rubber bands quickly perish.

(*j*) When tying, bags should be gently squeezed to expel excess air.

(*k*) Full bags should be stored in a well ventilated shed or shelter.

Specially constructed sheds should have boarded sides with ½ to 1 inch/*1.5 to 3 cm* gaps between boards on the east, south and west sides. For easy access, the north side should be open or boarded on part of its length only.

(*l*) Where plants in bags have to be stored for any length of time, bags should be packed one layer deep on shelves.

Bags must not be stacked several layers deep for more than a few hours, otherwise heating may occur. Where bags are stacked, it must be in such a way that air can get to at least one side of each bag.

(*m*) When plants are to be stored for more than a week in one place, it is important that the bags should be arranged so that the plants are more or less upright. For short periods, e.g. when in transit, this does not matter.

(*n*) **N.B. Plants must be kept out of direct sunlight at all times.** This is especially important in March and April.

*Duration of Storage in Polythene Bags*

Table 29 gives the maximum recommended safe storage period for the common forest species, when polythene bags are used.

Plate 1. A view of Glenfinart Nursery, in West Scotland, looking eastwards from above Glenfinart House. Glenfinart Forest is in the background. A4008.

Plate 2. Seed testing by means of a Copenhagen Tank. Seeds are placed on blotting paper under the funnels, the blotting paper being kept moist from water held in the tank. The temperature of the tank is closely regulated. Seed Testing Laboratory, Alice Holt Lodge, Farnham, Surrey. D4922.

Plate 3. Broadcast sown seedbeds at Kennington Nursery, near Oxford, showing, on the right-hand side, an oscillating spray-line. This one line is capable of watering all eight beds shown in the illustration. (Ken.).

Plate 4. Broadcast sowing by hand. Seed is being thrown against a "cuffing board". Using the board, seed is sown first along one side of the seedbed and then along the other side. Alice Holt Woodland Nursery. A7499.

Plate 5. Seed sowing by machine. This machine, a modified lawn fertiliser distributor, has been widely used for broadcast sowing of seed. The rate of seed is regulated by an adjustable gate. In the most recent models, the rate of sowing is regulated by different settings of a gear train. The machine can be tractor-drawn. B463.

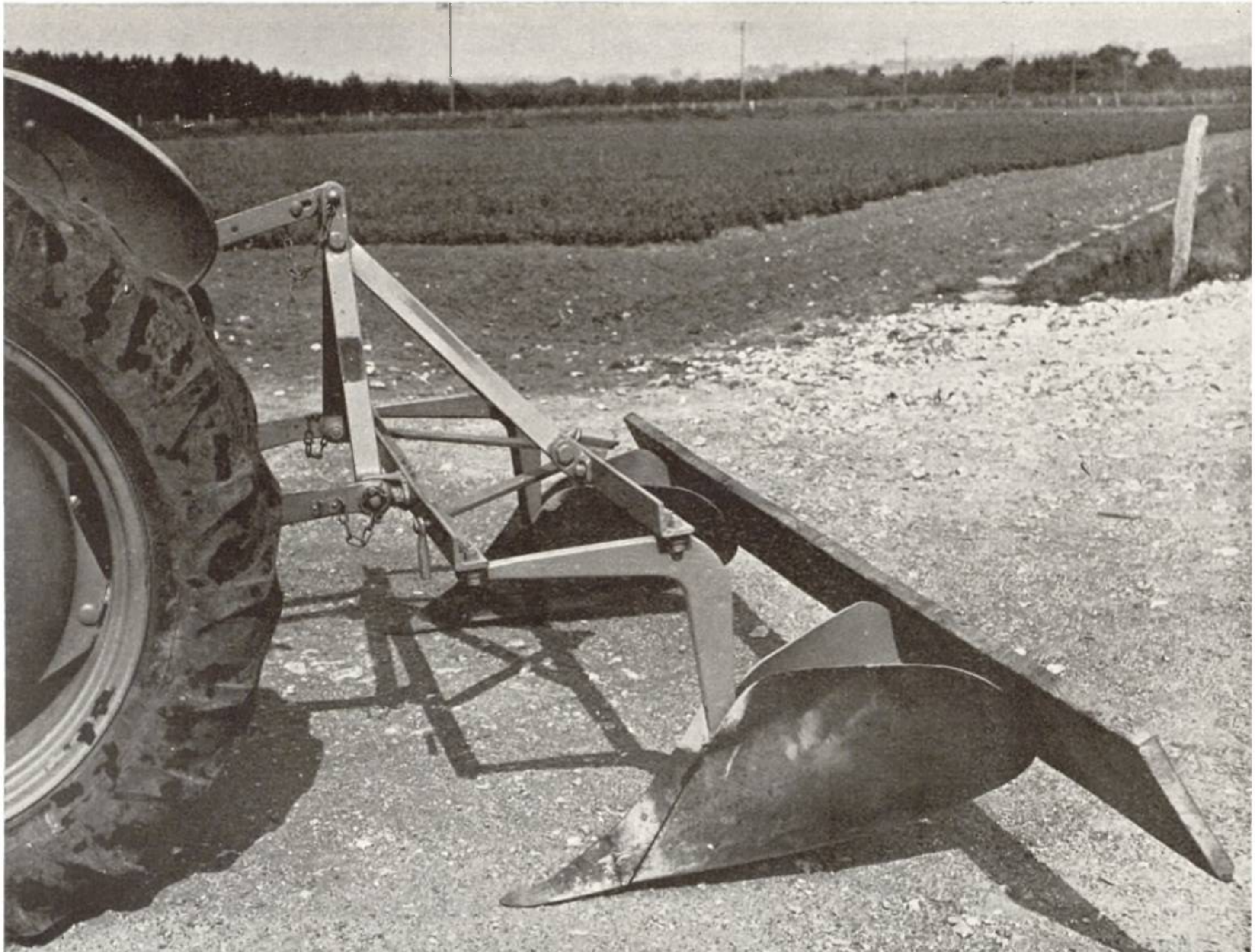

Plate 6. A machine for throwing-up seedbeds. This is a modified two-row potato ridger with the centre pair of shares removed. A board has been fitted between the two remaining pairs of shares in order to level the surface of the bed. Wareham Nursery, Dorset. C1288.

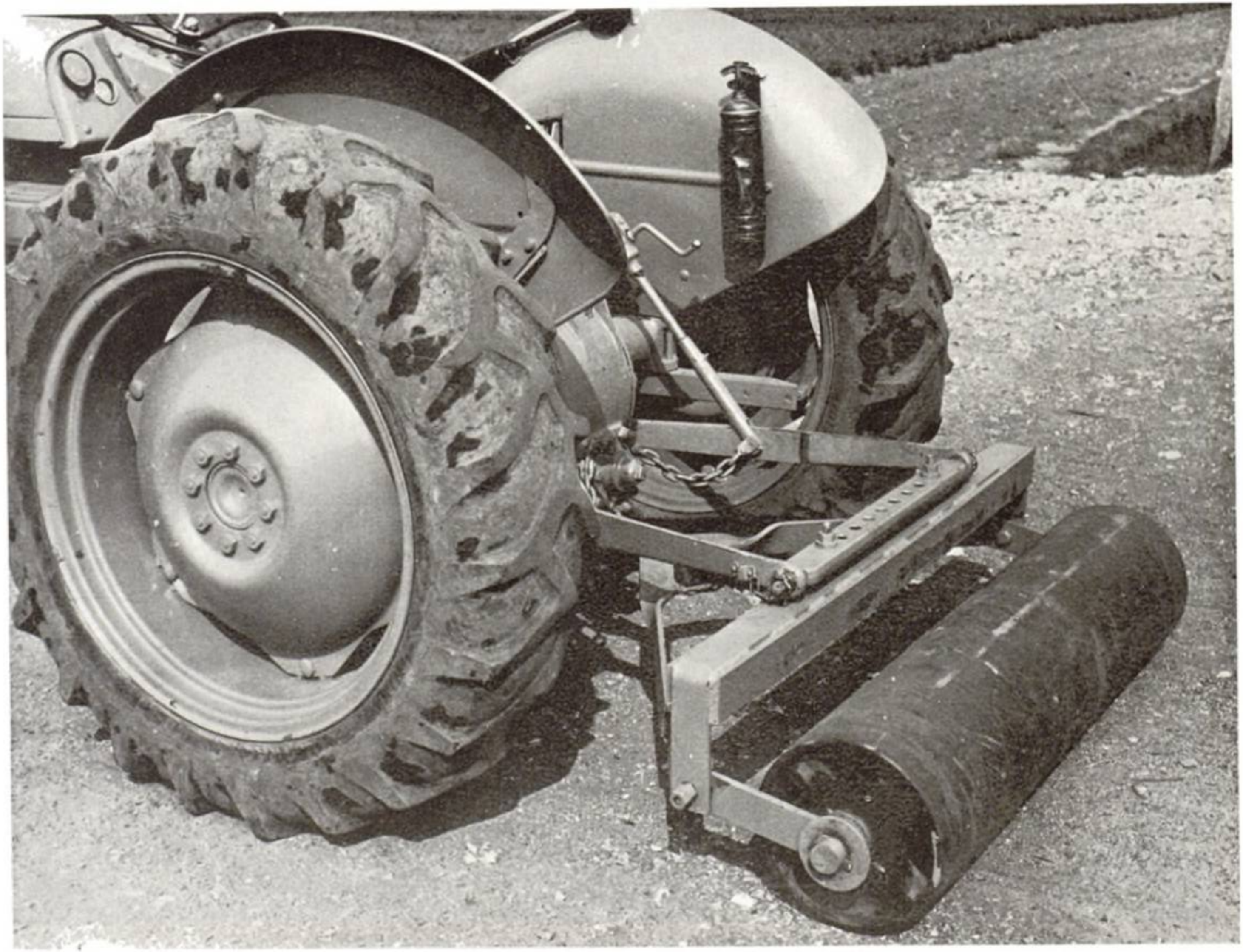

Plate 7. A seedbed roller. Wareham Nursery, Dorset.   C1291.

Plate 8. Seedbeds, immediately after having been drill-sown, and the drills covered in strips by grit. See Plate 9. B3791.

Plate 9. A machine for sowing seed in drills, and for covering them as shown in Plate 8. Ledmore Nursery, Perthshire. B4976

Plate 10. Lining out by hand in long lines. Note board on right. Bagley Wood Nursery, near Oxford. C257.

Plate 11. A section lined out by the Paterson method, using short boards across the beds, at right angles to the main direction of progress. C1294.

Plate 12. Lining out, using one of the earlier versions of the Ledmore Lining-out Plough.
Note boards. B4930.


Plate 13. The York Lining-out Plough, viewed from the rear. Four lines have been completed, the fifth board is in position and the sixth trench is being cut. D4965.

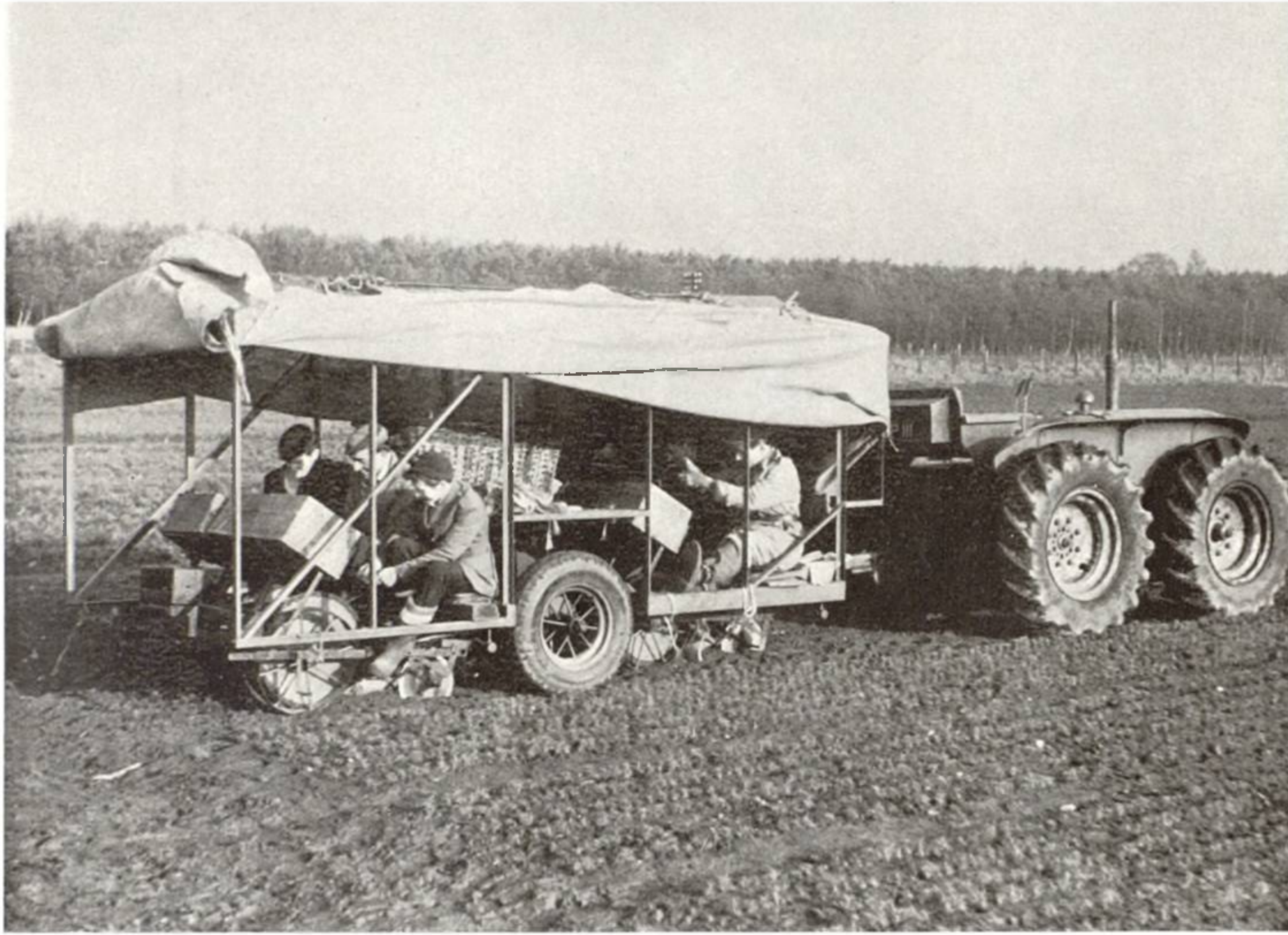

Plate 14. Holland transplanting units fitted to a specially constructed frame, so that six operators can work at one time. C3487.

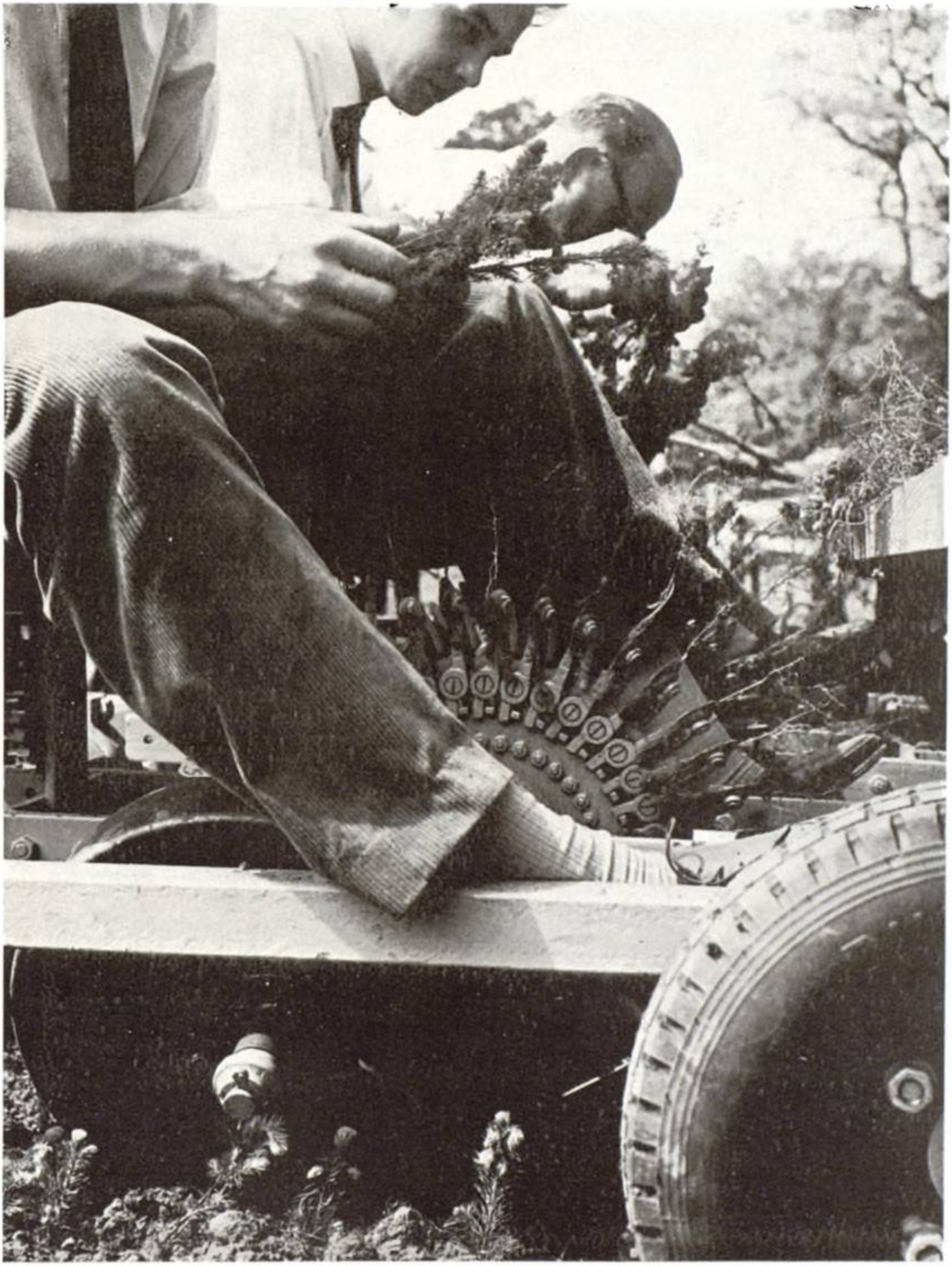

Plate 15. Close-up view of the planting wheel of the Super Prefer Lining-out Machine. B4541.

Plate 16. Sitka spruce one-year-old seedlings, newly lined out, and lifted out of the ground by frost. Wareham Nursery, Dorset. B181.

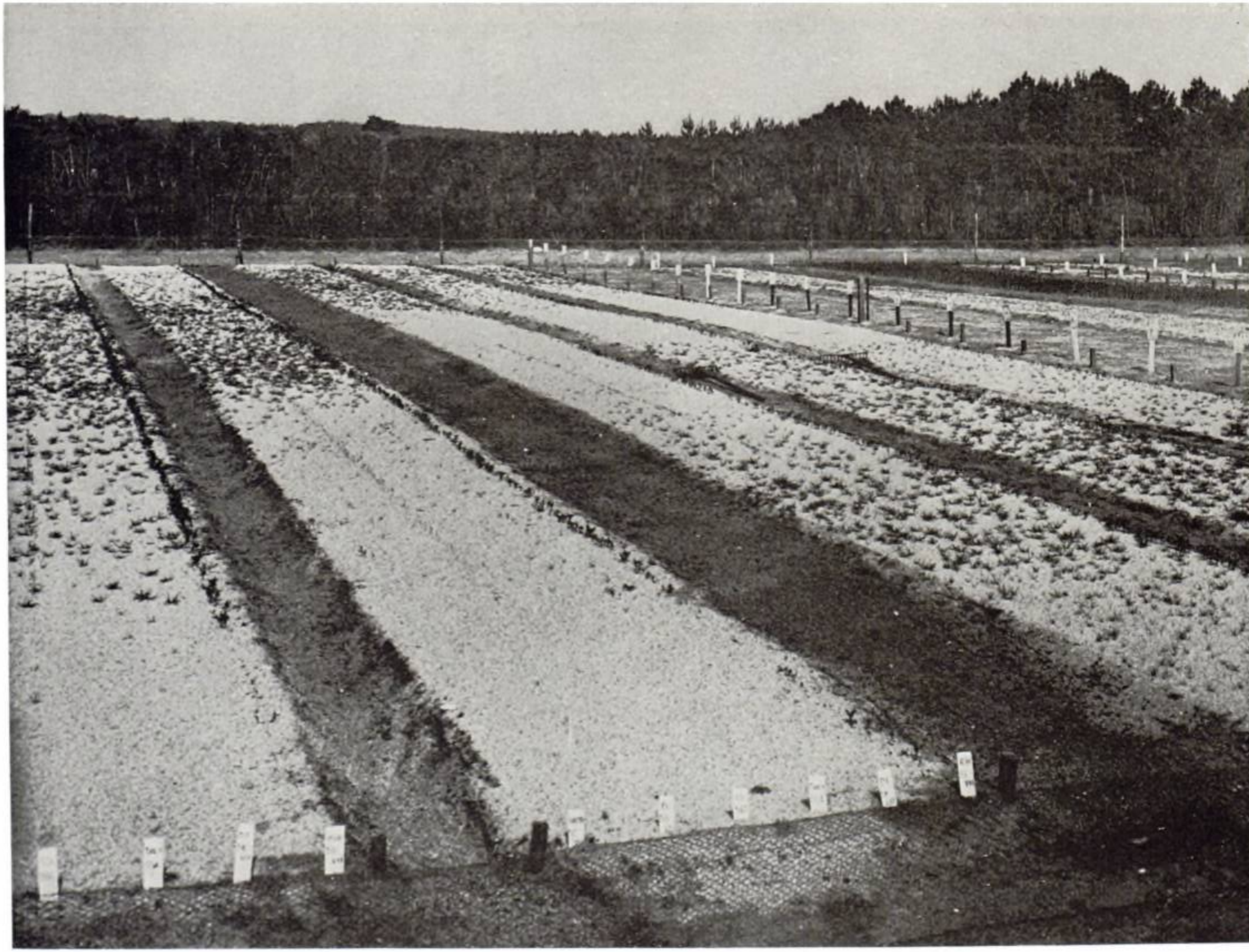

Plate 17. Experimental seedbeds where the pH of the soil has been varied experimentally. Weeds are prevalent on the areas where the pH is high; they are few or absent on the sections where the pH is low. B765.

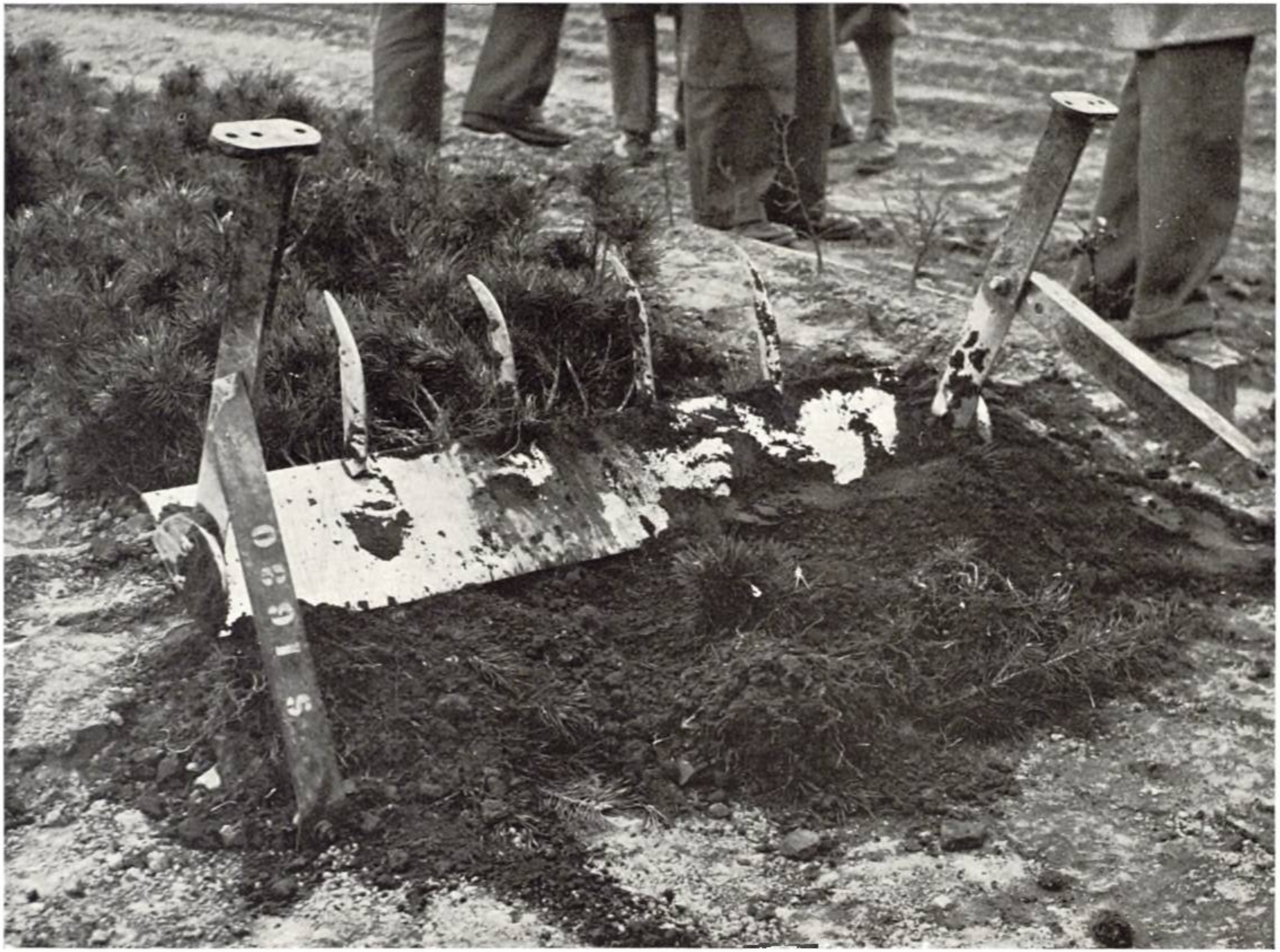


Plate 18. The Gunn plant lifter. B1430.

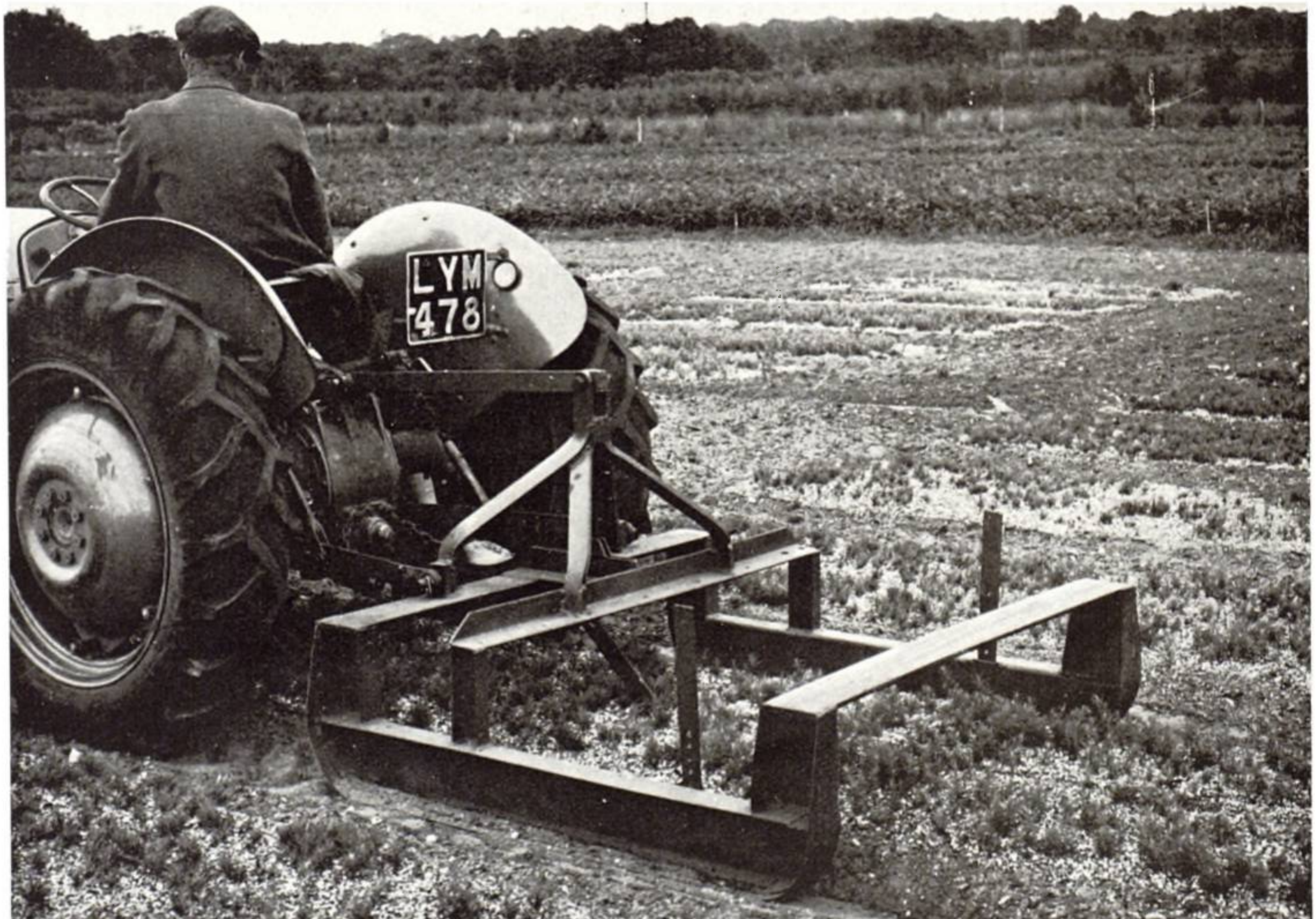


Plate 19. Blair Atholl Root Pruner undercutting Douglas fir seedlings at Elvetham Nursery, Bramshill.   B3525.

Plate 20. The Ledmore Root Pruner, undercutting Lodgepole pine seedlings at Glenfinart Nursery. C3996.


Plate 21. Reciprocating undercutter, showing adjustable depth control. Whereas the three lifters or root pruners shown in Plates 18–20 are fixed in relation to their frame, this undercutter blade reciprocates horizontally at right angles to the line of travel while the machine is in operation. B4140.

Plate 22. Weeding transplants by a spring-tine cultivator. The groups of very lightly sprung tines travelling between each pair of transplants lines readily uproot young weeds on light soils. On heavier soils, they are not so effective and a heavier tine is required. B4974.

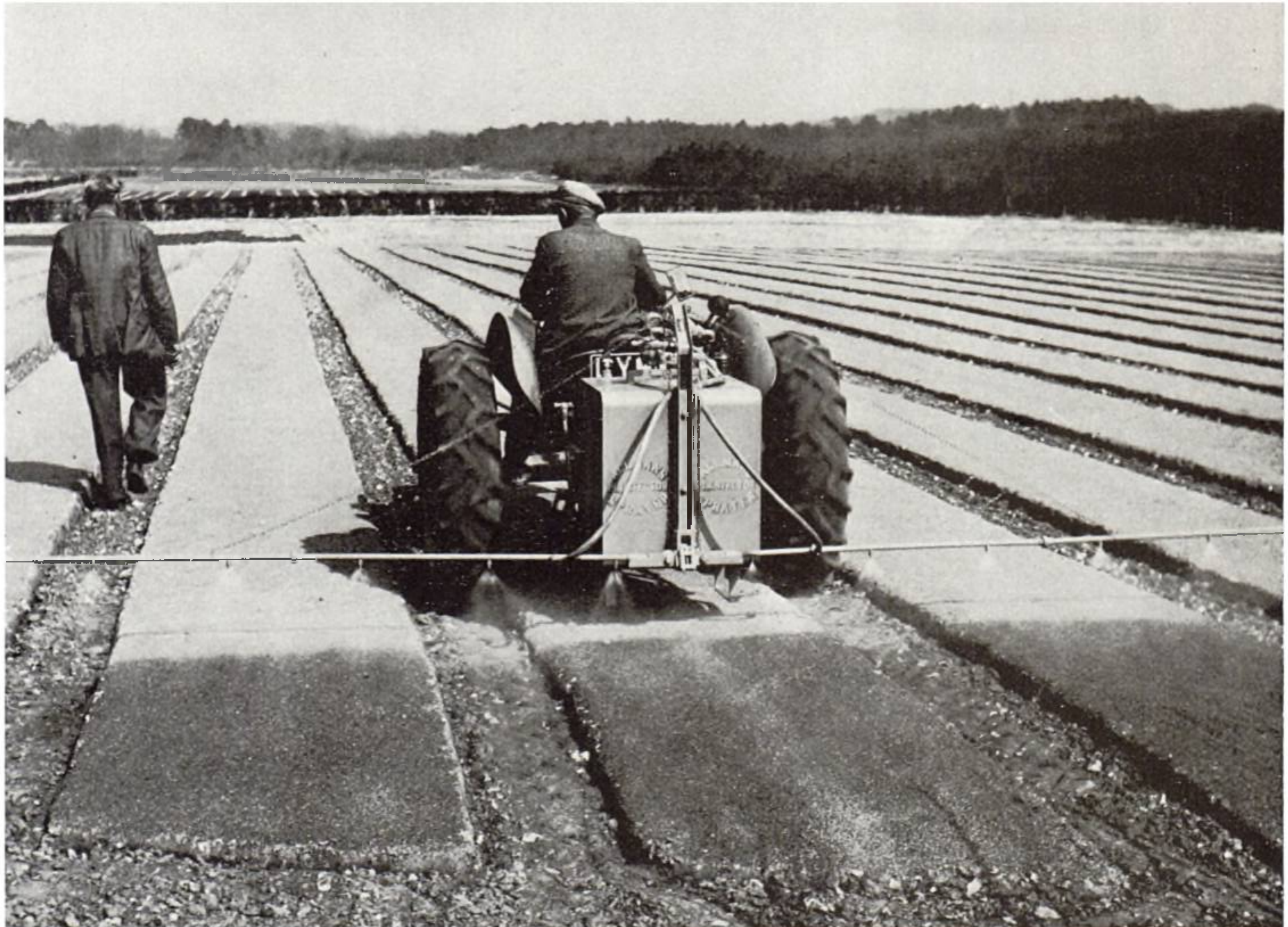

Plate 23. A rear-mounted sprayer and boom for pre-emergence and post-emergence spraying. B1350.

Plate 24. A boom—mounted under the belly of a tractor, for spraying between rows of transplants. Because the jets are nearer the ground than usual, they point towards the rear of the tractor, angled so that the spray swathe just covers the ground between any one pair of rows. B1562.

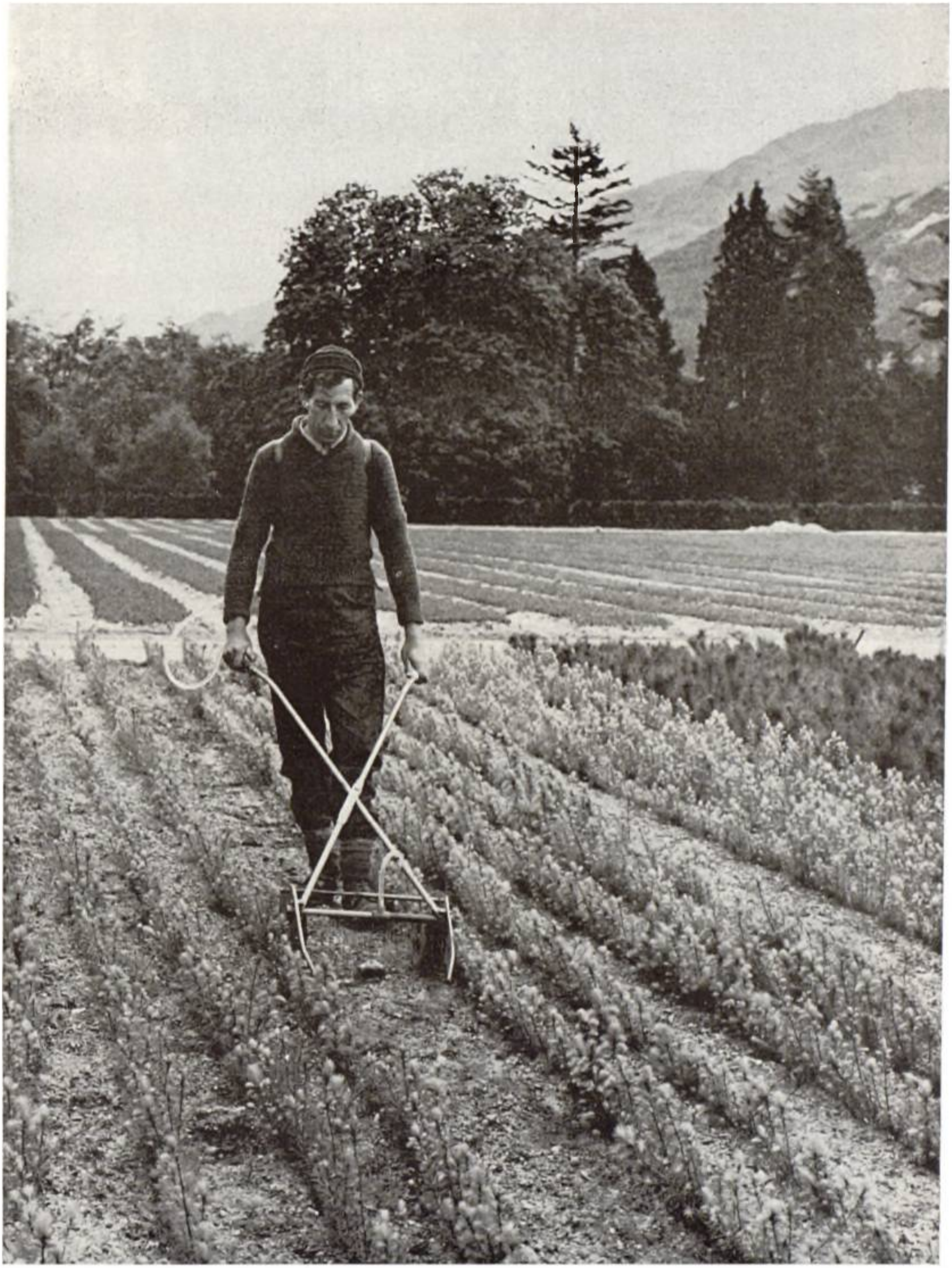

Plate 25. A prototype "dribble bar" being used to apply weedkiller between rows of transplants at Glenfinart Nursery. This tool gives a pattern of very coarse droplets, delivered at very low pressure. Foliage is deflected from the path of the implement by shields at either end of the bar. C3995.

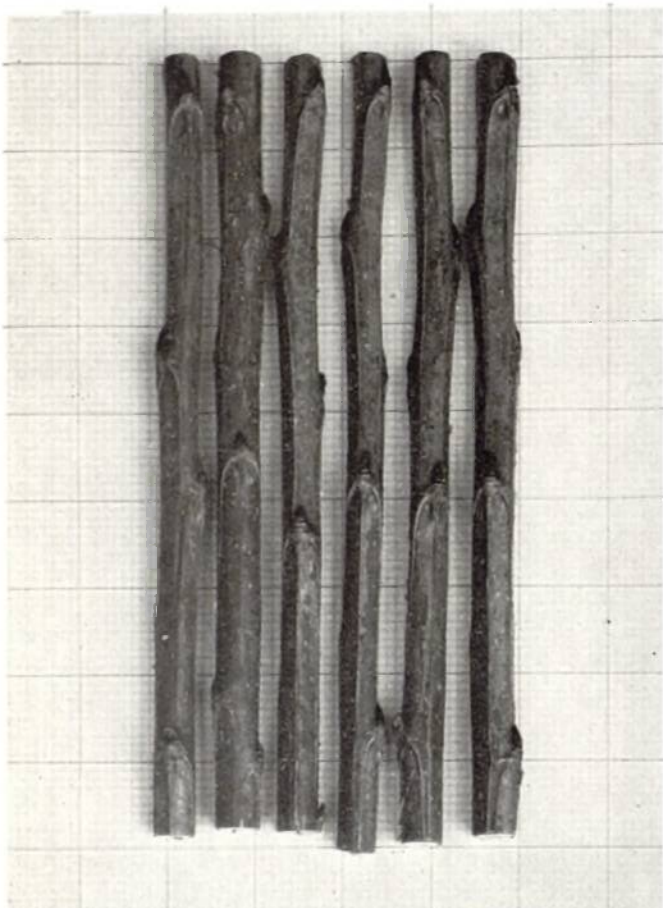

Plate 26. Cuttings of Black hybrid poplar. These are all one year old wood and illustrate good cuttings. D3801.
*Note:* The large background squares in Plates 26 and 27 measure 1 inch × 1 inch (2.5 cm × 2.5 cm).

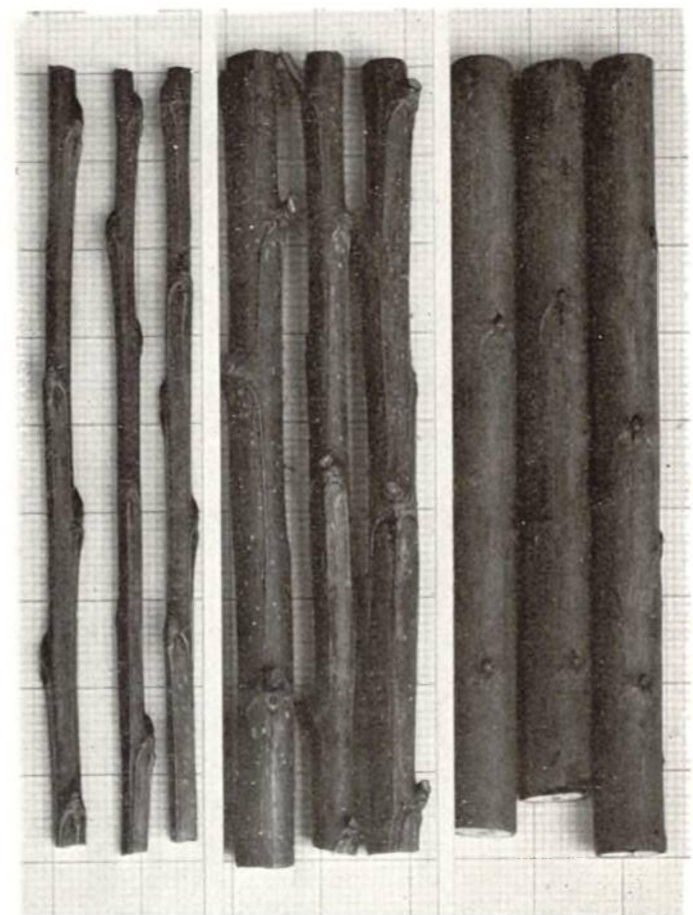

Plate 27. Bad quality cuttings of Black hybrid poplar. D3802–4. From left to right: cuttings which are too spindly, cuttings which lack buds and cuttings where the buds are so poorly developed as to give rise to weakly shoots in the following season.

Plate 28. *Populus* 'Robusta' plants at the end of the first growing season, having been raised from one-year unrooted cuttings, inserted the previous spring. Kennington Nursery, Oxford. D3298.

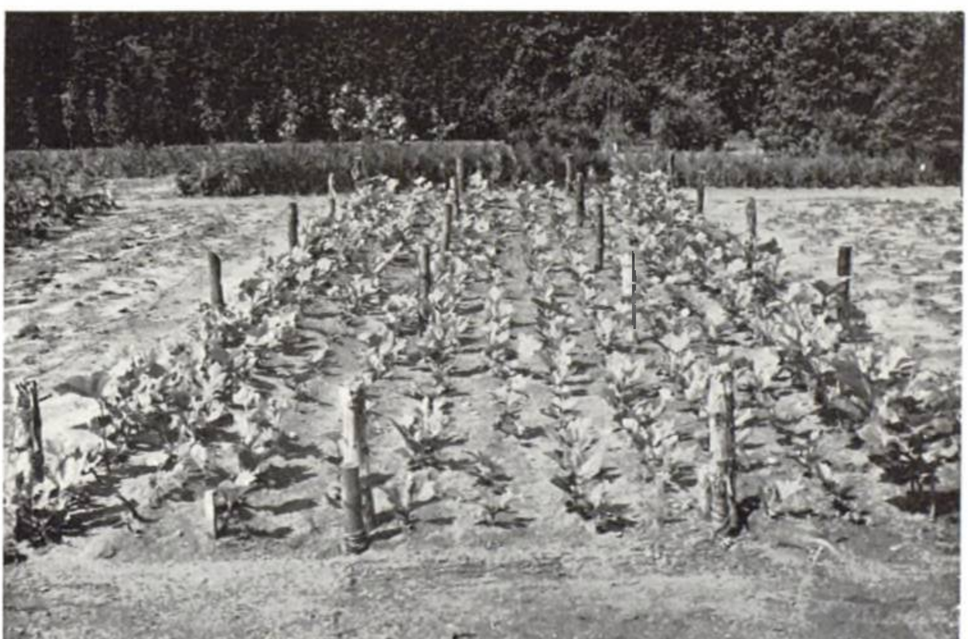

Plate 29. London plane cuttings being rooted in nursery soil. For the longer part of the growing season, these plants have been under hessian, which, in periods of warm weather, has been kept moist.

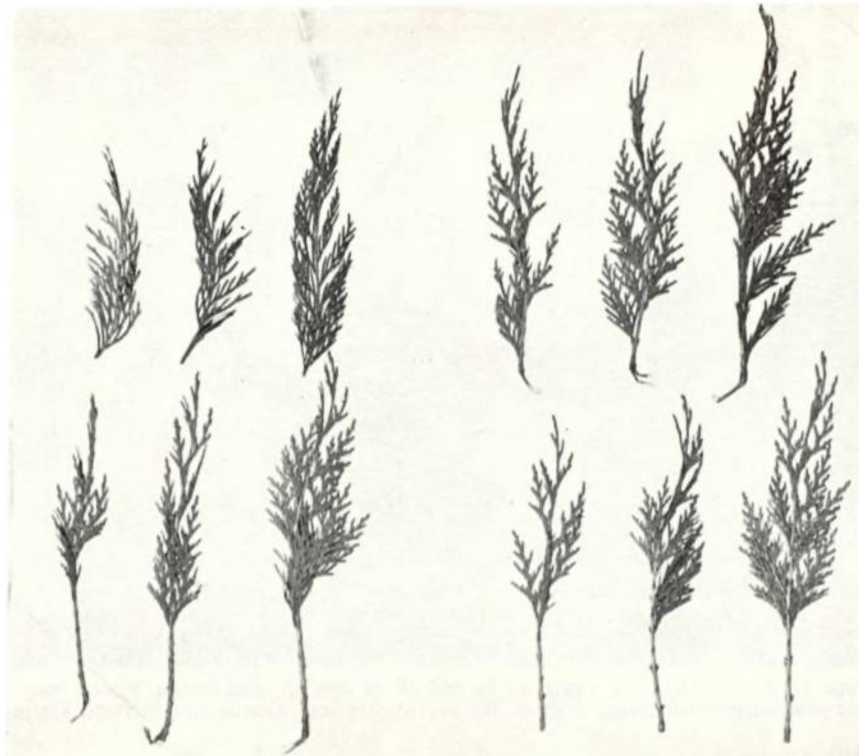

Plate 30. Leyland cypress cuttings in various stages of preparation for insertion. D6163.

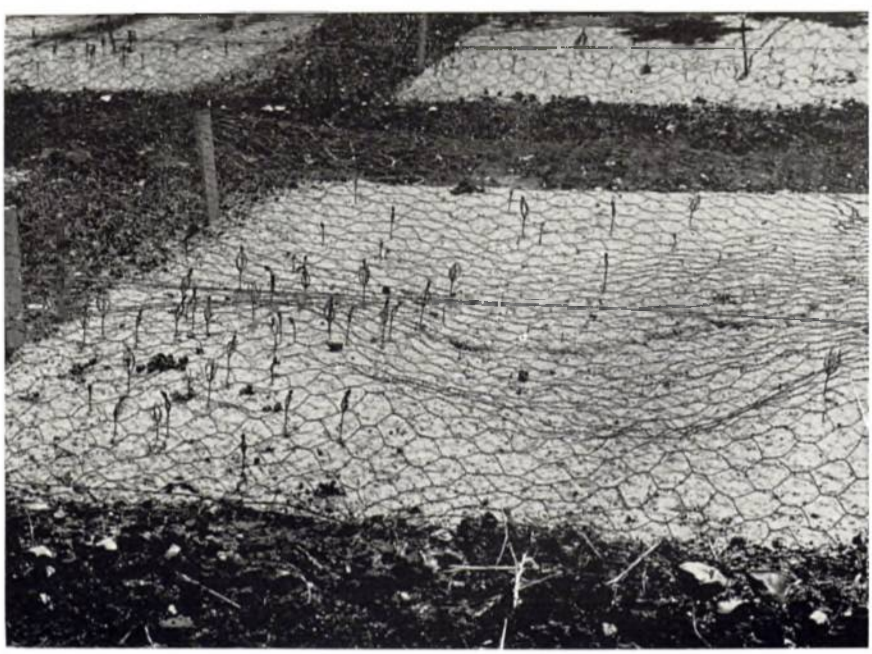

Plate 31. Bird damage to germinating seedlings of *Abies* species. The seedbed had been covered with wire-mesh netting which had sagged in the middle of the bed. Birds took emerging seedlings, by their seedcoats, where they could be reached through the netting. D5480.

TABLE 29

MAXIMUM RECOMMENDED STORAGE PERIODS FOR PLANTS IN POLYTHENE BAGS

| Species | Date of Lifting of Stock | | |
|---|---|---|---|
| | November–February | March (or up to the commencement of flushing) | April (or after flushing has commenced) |
| Norway spruce, Sitka spruce, Serbian spruce | Until mid-April | Until mid-April | Shortest possible time |
| Scots pine, Lodgepole pine, European, Japanese and Hybrid larch, oak, beech | Until mid-March | 3–4 weeks from lifting | Shortest possible time |
| Douglas fir, Corsican pine, Western hemlock, Western red cedar, *Abies* spp. Lawson cypress, *Sequoia* and *Sequoiadendron* spp. | 6–8 weeks from lifting | 3–4 weeks from lifting | Shortest possible time |

Normally plants should remain fully enclosed in their bags until required unless the safe storage period has been exceeded or bags damaged in transit, when they must be removed and examined for deterioration. There is no objection to opening bags for a short while to determine the condition or quality of the plants in the bags, and if plants have to be kept towards the end of the recommended safe storage period, regular inspection is well worth while, especially if the weather is warm or if there is any doubt that the storage conditions are adequate.

Plants starting to flush while in polythene bags must be removed and heeled-in.

### 9.34 Storage in Boxes

As an alternative to polythene, plants and especially seedlings may be firmly packed in open boxes, though not so tightly that they are crushed. The boxes may be quite empty or there may be a layer of peat in the bottom.

Seedlings packed this way can be stored in cool, well ventilated sheds for shorter periods than seedlings kept in polythene. The advantage of boxes is that the plants are easily seen and moulds do not develop. The main disadvantage compared with polythene is that plants dry out to some extent. Also seedlings stored in boxes take up more space and are less convenient to transport, unless a lorry is fitted up specially to take stacked boxes full of seedlings. Alternatively, the boxes for stacking may be made with projecting risers in the corners, to keep any box in a stack above the buds of the seedlings in the box immediately below.

### 9.35 Cold-storage of Plants

In Britain, cold-storage of plants during the early spring has only come into general practice since 1963. Other countries, notably Canada, United States and Norway have been exploiting cold-stores since 1959 or thereabouts.

Plants may be kept in any cold-stores operating at suitable temperatures by being stored in polythene bags. However, the more recent cold-stores built in horticultural nurseries are designed so that the store is in a jacket of cooled air, and the cooling unit has no direct access to air in the body of the cold-store. In jacketted stores, humidity is kept up by open tanks of water and plants can be stored unwrapped without the need for any protection against drying out. Staff can work in such stores, sorting and grading plants if required.

*Short-term Storage of Seedlings and Transplants in Cold-stores*

The primary advantage of cold-stores over open ventilated sheds for short-term storage is in preventing plants from starting to grow in the late spring. Plants stored in polythene bags in an open shed will start to grow inside the bags as soon as the air temperature is sufficiently warm; such plants usually lose all their new growth when lined out. If instead, plants can be kept cold and moist in a cold-store, they will remain dormant and will grow normally when transplanted.

Norway spruce seedlings cold-stored and lined out in June have sometimes grown better than have others from the same seedbed lined out in late spring.

*Long-term Storage of Seedlings in Cold-stores*

Some species can safely be stored until the middle of summer before lining-out. The main effect of such a practice is that the plants so stored make less than normal growth in the year of storage and at the end of three years are little bigger than normal two-year-old plants. Surplus plants can be stored this way as an alternative to destroying them or standing them over in seedbeds for a second year. Standing over is undoubtedly the cheapest means of holding over surplus plants but the seedlings at the end of two years are generally bigger than cold-stored plants and if this is inconvenient, or if the seedbed area is required for the current year's crop, cold storage may be preferred.

*Recommendations for Cold-storage of Seedlings*

Plants must be healthy and fully dormant when lifted. Lifting should preferably take place in February or early March.

Plants must be stored in polythene bags unless the store has a cooling jacket rather than a cooling unit inside the store itself; the surface of the foliage must be dry when plants are put into the bags, which must be in good condition and should fully enclose the plants. Bags must be so arranged in the store that there is a free air flow around at least two sides of each bag.

In jacketted stores, plants need not be kept in polythene bags. If bags are not used, there should be two or three large open tanks of water in the store, to keep a high relative humidity.

The temperature should be kept as steady as possible in the range between —2° and +2°C. The experimental work leading to this recommendation was restricted in that facilities were not available for storage at —1° or —2°C. However, recent work on the Continent indicates that storage at these temperatures give as good results as storage at +2°C and that there may be less condensation in bags and mould growth at the lower temperatures.

All the commonly planted forest species have survived storage until late May under the conditions given above, and can be recommended for short-term storage.

The following species are suitable for long-term storage: Norway and Sitka spruce, Douglas fir, Lodgepole and Scots pine, Western hemlock, oak and larch, probably also Lawson cypress and *Abies grandis*. Stored plants should be transplanted in the period from June to early August. Plants lined out later than this are likely to be severely damaged by autumn frosts.

Japanese larch is not suited to long-term cold storage.

Insufficient is known about other species to make any recommendations.

Advance provision must be made to water plants after long-term storage should the weather turn dry. Sufficient summer rain cannot be guaranteed—not even in the British climate!

## 9.4 Despatch

The nursery manager having to organise the sending of plants from his nursery to a forest planting site may often find himself in a dilemma. On the one hand, he wants to reduce to the minimum the time between lifting, despatch and planting; on the other hand, the most economic means of transporting plants is usually a lorry load at a time. Loads of this size normally take a few days to assemble and at the forest, though some plants may be put in immediately, some may have to wait a couple of weeks before being planted.

The risks to plants in such situations can be reduced to a minimum only by good storage facilities and by close contact between the nursery manager and the forester receiving the plants—adjusting the programmes of lifting and despatch on the one hand and planting on the other.

A nursery manager should encourage his customers to give him two months' notice of when plants are required, and a name and a phone number so that any last minute arrangements can be agreed.

### 9.41 Methods of Packing

In many cases where speedy 'door-to-door' delivery of plants by lorry can be arranged, no special packing is required other than careful stacking on the vehicle. See 9.42 below. However, if there is any doubt, plants should be protected by baling or carriage in a hamper or crate.

*Hessian Bales*

These are best used to send small lots of plants by rail (passenger service). Formerly, plants were packed root to root with sphagnum moss around the roots. Shoots and roots were then covered with a 2 inch/*5 cm* layer of straw, with extra round the leading buds to protect them. The bale was then sewn up with binder twine, the ends of the bale being sewn last to reduce pressure on the leaders. Since the advent of polythene bags, most foresters have omitted the straw and moss, packing the plants in polythene and making a hessian bale of the bags.

Where a few tall transplants, especially hardwoods have to be sent in a bale, a stiff stick, an inch or so longer than the longest plants, should be packed in the bale to prevent the tips of the shoots being snapped off in transit.

*Wicker Baskets or Hampers*

These, like the hessian bale, have been a traditional means of sending plants by rail, a customary size being 3 ft x 2 ft x 1½ ft/*1 m x 0.7 m x 0.5 m*. More plants can be packed in a hamper than in a bale. The disadvantage of hampers is that they are quite expensive to buy. They are returnable but have often been used as a temporary means of storing plants at the planting site, when their return may be delayed.

Plants used to be packed in lined hampers using sphagnum moss round the roots and straw between layers of plants, but again polythene bags have largely replaced straw and moss. Where large numbers of seedlings are packed in polythene bags in a hamper, it is worthwhile putting one or more layers of straw or twigs between the layers of bags to improve the ventilation in the middle of the hamper. If polythene bags are used, hampers should not be lined, but the inside should be examined carefully, cutting off any projecting bits of wickerwork which could damage the bags.

*Wire Mesh Bales*

These have been used locally for despatching plants but this practice has not caught on generally.

### 9.42 Methods of Despatch

Hessian bales, hampers, wire bales, etc sent by rail must be sent by the speediest and most certain means. Passenger train is usually best but enquiries should always be made to see if there is an express goods service which would ensure as speedy a delivery at a lower cost.

*Lorry*

Door-to-door delivery by lorry is by far the most satisfactory means of transporting large numbers of plants, especially if these have been packed into polythene bags or heeled in.

Loads of plants despatched by lorry should be no more than two layers of bags deep. If more plants than this have to be taken, some staging, shelving or other means of separating the plants must be improvised. Lorries regularly used for delivery of plants should be fitted with a permanent system of shelving. Boxes of seedlings are suitable for movement by lorry, especially if the boxes are designed to be stacked safely without damage to the seedlings.

If plants are being sent without protection being given by boxes or polythene, they should be arranged in cones, with roots of all plants in the cone to the middle, shoots pointing out and wet moss in the middle around the roots. The stack should taper upwards with the centre filled with upright plants.

All plants sent by road, whether in polythene or not, must be covered with a tarpaulin for the whole of the journey. Any tarpaulin put over plants not packed in polythene must be particularly well tied on so that the least possible amount of air gets in and dries the plants. Transparent polythene sheets must not be used instead of tarpaulins as clear polythene does not protect plants from the heating effect of sunlight; this can cause serious loss if the plants are also enclosed within polythene bags.

*Railway Van*

Plants may economically be sent long distances by rail if the load may be expected to fill a van more than half full. Transport by rail is usually more expensive than transport by road but may be justified if a suitable lorry is not readily available.

In this case, no special outer wrappings of hessian or hampers are required and plants can be packed as described above for a lorry. It is essential to ensure that the van concerned, firstly, is ventilated and is either unheated, or better, is insulated and secondly that it can travel either attached to a passenger train or by "express" goods train or any other system that ensures that the van gets to its destination within two days. Transport of plants by railway van has the disadvantage of additional handling into and out of the railway van, whereas a lorry can go from nursery to a point near the planting site in one journey. This disadvantage can be overcome by use of an insulated railway container which can be delivered to the nursery for loading, is transferred to a flat waggon for the railway part of its journey and can be taken off and delivered by road to its final destination.

### 9.5 Labelling

All consignments of plants sent by public transport must be clearly labelled. Two labels each showing the destination and the sender should be wired onto each package, whether bale, hamper etc. Inside one of the packages, there should be a despatch note repeating the information on labels and, in addition, giving a brief summary of the number of plants and species in each package and a statement of the number of packages in the consignment. A copy of this despatch note should also be sent by post.

Consignments sent by lorry or railway van should be clearly marked so that the number and species of plants do not have to be determined by opening the bags. The driver of the lorry should carry a despatch note giving full details of the consignment.

#### Further Reading

Aldhous, J. R., 1959. Polythene bags for movements of nursery stock. *Empire Forestry Review*, **38** (95), 65–76.

Aldhous, J. R., 1964. Cold-storage of forest nursery plants; and trials, 1958–63. *Forestry*, **37**, 47–63.

Brown, R. M., 1971. Cold-storage of forest plants. *Quarterly Journal of Forestry*. **65** (4), 1–11.

Faulkner, R., 1957. The storage of one-year conifer seedlings. *Report on Forest Research*. 1956, 123–131.

# Chapter 10
# WEED CONTROL

Every nurseryman aims to produce first class stock as cheaply as possible. In the large majority of nurseries, however, weeds are an obstacle in the path to this target and their elimination can be costly.

### 10.1 Competition from Weeds and General Nursery Hygiene

There can be no doubt that heavy weed growth checks growth of young trees. In one study, the height of Sitka spruce seedlings was reduced by up to 20 per cent by heavy weed growth. There have also been several instances in dirty nurseries of substantially better growth by transplants kept free from weed competition, with simazine or other means.

In addition to any competition effect, seedlings may be removed accidentally along with big weeds. In one nursery, counts made before and after weeding a larch seedbed showed that about 35 per cent of the seedlings had been removed or buried during the one cleaning. This particular count was made in the period before regular pre-emergence sprays. Nevertheless, the tendency remains for seedlings to be lost when removing big weeds from weedy seedbeds.

The objective of all steps taken to control weeds should be to break the life-cycle of each unwanted species and prevent it from reproducing, whether by seed or vegetatively. If this is achieved, the number of dormant weed seed and other perenniating parts in the soil is gradually exhausted, and more and more of the time spent controlling weeds is taken up, quite properly, with searching rather than weeding. Failure to prevent seeding or vegetative proliferation means that an annual crop of weeds is removed with no long-term benefit. The old adage "one year's seeding brings seven years' weeding," with all its implications on costs, applies to forest nurseries as much as to the farm.

### 10.11 All-the-year-round Weed Control

Many weeds can set fertile seed within a few weeks of germinating and can complete four or five generations in a year. There is no dormant season for certain of these weeds, some species growing, flowering and fruiting during mild winter days as successfully as in the autumn or spring. The forester or nurseryman must, therefore, be prepared to keep his weeds under control at all times of the year. There can be no respite if he wants to keep on top.

The task of killing weeds is a lot easier if new introductions of seed from bulky organic manures, weedy fence lines and surrounds of buildings, etc, can be prevented. The cleaner the nursery, the more particular the man-in-charge must be to avoid contamination in this way.

*Organic Manures*

Two convenient forms of organic manure for forest nurseries are chaffed bracken and spent hops, whether used singly or together. Manures based on straw or dung, whether or not broken-down or composted, should be excluded from the nursery. In an agricultural trial at Woburn, it was found that in two years, under a regime expected to keep weeds in check, weeds increased by 50 per cent on plots given manures containing dung or farmyard manure, compared with plots not treated in this way.

*Fence Lines and Uncultivated Land*

Fence lines surrounds of buildings, and ditch banks can all harbour weeds. These are best kept bare of vegetation by regular cultivation or use of a complete weed-killer such as simazine or by regular spraying with vaporising oil or with a paraquat/diquat mixture. If this is impracticable for any reason, a close perennial vegetation cover should be established which will itself exclude other weeds and not give rise to unwanted seeds or vegetative parts.

*Keeping a New Heathland Nursery Clean*

New nurseries can often be sited on heathland where few weeds have ever grown, and there is no "reservoir" of seeds. In such nurseries, it is doubly important to observe not only the precautions described in the two preceding paragraphs but also to take the precaution of growing in the nursery all the seedlings to be transplanted there, bringing in no seedlings whatsoever.

Experience has proved that many weed seeds and even growing weeds are introduced with seedlings from outside and that thereby one of the tremendous initial advantages of the heathland nursery is lost. With strict nursery hygiene and a relentless search for weeds, the annual cost of weeding can be kept down to £25 per acre/*£60 per hectare.* In less fortunate nurseries, weeding regularly costs £100 to £200 per acre/*£250 to £500 per hectare.* (1970 values).

### 10.12 Major Weeds in Forest Nurseries

The more important weeds that occur in forest nurseries are listed in Table 30. It will be seen that the list of those generally present is relatively short. *Poa annua*, the Annual meadow grass, is probably the most important weed on the list, and is present almost everywhere though it is less important on

TABLE 30
WEED SPECIES IN FOREST NURSERIES
From a Survey in 1959

| | | | |
|---|---|---|---|
| I. SPECIES PRESENT IN MOST NURSERIES (OFTEN IN LARGE NUMBERS) | | | |
| *Annuals* | | *Perennials* | |
| *Poa annua* | Annual meadow grass | | |
| *Senecio jacobea* | Groundsel | | |
| *Spergula arvensis* | Corn spurrey | None | |
| *Stellaria media* | Chickweed | | |
| *Capsella bursapastoris* | Shepherd's purse | | |
| II. WEEDS PRESENT IN A NUMBER OF FOREST NURSERIES (SOMETIMES IN LARGE NUMBERS) | | | |
| *Annuals* | | *Perennials* | |
| *Polygonum persicaria* | Redshank | *Rumex acetosella* | Sheep's sorrel |
| *Urtica urens* | Annual nettle | *Ranunculus repens* | Creeping buttercup |
| *Chenopodium album* | Fat hen | *Agropyron repens* | Couch grass |
| *Sinapsis arvensis* | Charlock | *Rumex* spp. | Docks |
| *Cerastium holosteoides* | Mouse-ear chickweed | *Chamaenerion angustifolium* | Rose-bay willow herb |
| *Polygonum aviculare* | Knot-grass | *Taraxacum officinale* | Dandelion |
| | | *Sonchus* spp. | Sow thistles |
| | | *Erica* spp. | Heaths |
| | | *Calluna vulgaris* | Heather |
| | | *Pteridium aquilinum* | Bracken |
| | | *Sagina procumbens* | Pearlwort |
| III. WEEDS OCCASIONALLY FOUND IN FOREST NURSERIES | | | |
| *Annuals* | | *Perennials* | |
| *Erophilla (Draba) verna* | Whitlow grass | *Sedum acre* | Stonecrop |
| *Chrysanthemum segetum* | Corn marigold | *Oxalis* spp. | Wood sorrels |
| *Spergularia rubra* | Sand spurrey | *Convolvulus arvensis* | Bindweed |
| *Viola tricolor* | Heart's ease | *Lamium* spp. | Dead nettles |
| *Thlaspi arvense* | Field penny cress | *Veronica chamaedrys* | Germander speedwell |
| *Fumaria officinalis* | Common fumitory | *Holcus lanatus* | Yorkshire fog |
| *Matricaria recutita* | Wild chamomile | *Potentilla* spp. | Potentillas |
| | | *Chrysanthemum vulgare* | Tansy |
| | | *Bellis perennis* | Daisy |
| | | *Achillea millefolium* | Yarrow |
| | | *Trifolium repens* | White clover |
| | | *Plantago* spp. | Plantains |

heavier soils than on light ones. It is a species which responds to soil acidity in a similar way to many conifer species (see Appendix V, and Plate 17). *Poa annua*, chickweed and one or two other weeds can set seed in as little as four weeks from germination and it is this characteristic that makes them so troublesome. Many of the annual weeds of market gardens and shrub and ornamental nurseries are less common in forest nurseries because the soils of the latter are generally more acid and lighter.

Perennial weeds are not always found in forest nurseries and their presence is often a sign of mismanagement (e.g. of introducing weeds with roots of plants or of bad selection of site of the nursery). Certain species, e.g. Sheep sorrel (*Rumex acetosella*), are tolerant of acid soils and can become widespread in heathland nurseries. In newly-made nurseries, there are also those perennials (e.g. bracken, heather) which belong to the previous vegetation cover; these usually disappear after a year or two of intensive weeding.

The cultural routine of forest nurseries almost always includes one year in three or four when the soil is bare fallow or is green-cropped; this year should always be used to eliminate any perennial weeds which are established in the nursery. Specific recommendations for the control of the most troublesome perennials are given in Section 10.6.

### 10.13 Definition of Terms

The terms used to define the stage of growth of the crop in relation to weed-control treatments are:

*Pre-sowing:* Before sowing.

*Pre-emergence:* Before the emergence of seedlings of the crop which was sown but after the emergence of weed seedlings.

*Post-emergence:* After seedlings of the crop sown have begun to emerge from the seedbed.

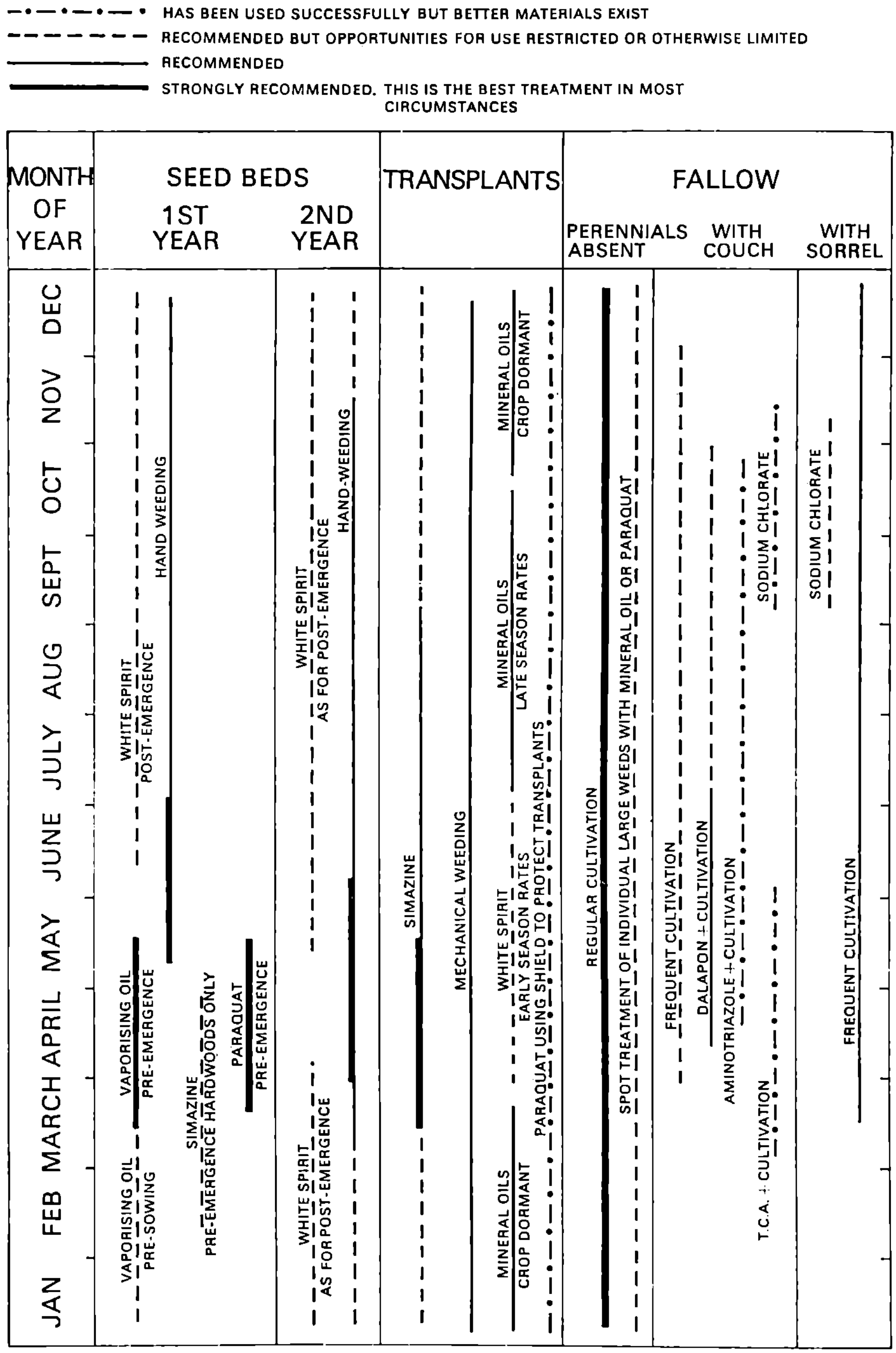


Fig. 4. Weed Control Schedule: Alternative treatments for various kinds of nursery ground.

*Dormant:* After the shoots of seedlings or transplants have ceased to elongate and have hardened off, terminal (and side) resting buds having formed but before the buds have commenced to grow at the beginning of the following growing season. For deciduous species, when, in addition, the foliage has taken on its autumn colouring, or has been cast.

The following terms define the distribution of sprays (or the location of weeding operations) in relation to the crop:

*Overall:* Directed onto the crop and weeds without distinction.

*Inter-row:* Directed onto the weeds and the ground between rows of transplants or between drills of seedlings.

### 10.14 Recommendations for Weed Control in Seedbeds, Transplant Lines, Fallow, etc.

Figure 4 shows the alternative measures which can be used at any given time for seedbeds, transplants, and fallow. Full details of each technique are set out in subsequent sections. While each is listed separately below, it is most important to emphasise that no one method is sufficient in itself to give a satisfactory and economical control of weeds. The various techniques described should be visualised as weapons in an armoury, the most suitable being selected according to the conditions and available equipment. A nurseryman wishing to keep his weeds under control as cheaply and efficiently as possible must be prepared to change from one technique to another when appropriate. Exclusive adherence to any one technique could lead to a rapid build up at one or more species of the weed flora.

### 10.2 Chemical Control of Weeds: General

Chemical weedkillers, or herbicides, are the principal means of controlling weeds in the large majority of forest nurseries in Britain. Three or four herbicides, vaporising oil, simazine, paraquat and white spirit meet most needs.

Many of the other chemical weedkillers put on the market since 1945 have been tested on conifer or hardwood seedbeds or transplant lines, but have been rejected either because they damaged the crop or because they did not give adequate weed control. Brief accounts of experiments with such materials are given in the Forestry Commission *Reports on Forest Research* from 1949 to the present, in the chapters headed "Nursery Investigations".

The recommendations which follow refer to the active ingredient in weedkillers rather than to any particular brand. However, approved proprietary brands of these and most agricultural pesticides can be found in the "*List of Approved Products*" produced annually in February by the Ministry of Agriculture, Fisheries and Food. Copies can be obtained from local M.A.F.F. Divisional offices or from M.A.F.F. (Publications) Block C, Tolcarne Drive, Pinner, Middlesex or in Scotland and Northern Ireland, from the main office of the respective Departments of Agriculture.

### 10.21 Materials Used on Weeds in Seedbeds and Lines

*Mineral Oils*

Mineral oils are contact weedkillers, that is to say they cause the immediate death of the tissues of susceptible species with which they come into contact. The oils recommended for use in forest nurseries are not persistent but evaporate quickly into the air.

The two types of oil recommended are:

(*i*) *Vaporising Oil* (specific gravity: 0.82, boiling range: 140–250°C, aromatic hydrocarbons: 12–35 per cent).

Tractor fuels such as those marketed by 'Shell' and 'Esso' have met the necessary specification. However, their composition varies according to the sources of crude oil and especially when contemplating inter-row spraying of transplants, it is always worthwhile to spray a small trial area first before embarking on a big spraying programme with a previously untried oil.

(*ii*) *White Spirit* (boiling range: 150–200°C, aromatic hydrocarbons: 15–20 per cent).

Shell "W" and Esso white spirit have been used successfully, but white spirits other than Shell "W" have the same limitation as vaporising oils, i.e. that they are not manufactured specifically as weed killers. Any new batch of oil should therefore be tested on a small scale and only used extensively if no damage to the crop follows within twenty-four hours of testing.

When using mineral oils to control weeds, it is essential to remember that the oils are most effective when the weeds are *very small*—not more than 1 inch/*2.5 cm* high and preferably in the 2 to 3 leaf stage. Oils applied at rates safe for the forest seedling or transplant crop may only scorch and check bigger weeds, and if the bases of the stems and the roots of the weeds are not killed, shoots will rapidly grow again.

*Precautions when Applying Vaporising Oil or White Spirit*

Spraying must be avoided in periods of drought or very warm weather. Sprays may be applied in wet spells, provided foliage is dry at the time of spraying.

*Paraquat and Diquat*

Paraquat and diquat are contact herbicides which are rapidly inactivated by absorption onto clay or humus particles in the soil. Paraquat is more effective against grasses while diquat gives a better control of broadleaved herbaceous weeds.

In the forest nursery, paraquat has recently come into use as a cheaper alternative to vaporising oil pre-emergence sprays.

Paraquat or a mixture of paraquat and diquat can be used to control weeds on waste land in any situation where established shrubs or trees root so near the surface that residual herbicides like simazine cannot safely be used.

**Precautions when applying Paraquat or Diquat**

**Those handling the concentrate must always wear rubber gloves and a face-shield or other equipment which can protect the eyes, mouth and nose from splashes.**

*Keep the concentrate under lock and key when not in use and away from children at all times.*

*When spraying the diluted solution, the spray pressure should, if possible, be kept low, i.e. at* 10 *to* 15 *pounds per square inch.*

*Avoid inhaling spray drift.*

*Simazine*

Simazine is a residual weedkiller and does not enter plants or weeds through the foliage. It is only very slightly soluble in water and is carried down in suspension by rain water into the surface ½ to 1 inch/*1 to 2 cm* layer of the soil, where it is taken up in very small quantities by any plant roots growing there. Within the plant, it is translocated to the leaves where it interferes with the chlorophyll metabolism and synthesis of sugars and, if taken up in sufficient quantity, brings about death of the plant.

In forest nurseries, simazine has found an important place controlling weeds in transplants. It has largely replaced vaporising oil in this role. The selective action of simazine in a nursery depends on contrasting rooting depths. Transplants root below the zone penetrated by the herbicide, while the first roots of weeds, germinating near the soil surface, come into immediate contact with any simazine present there. Established deep-rooted weeds can be expected to be immune from the effects of simazine, and shallow-rooted forest trees to be relatively susceptible (though conifers are somewhat more resistant than most plants).

Simazine applied to loose or partially compacted soil may be washed more deeply into the soil than if the soil is well compacted. Soil around transplants should therefore be reasonably firm when simazine is applied.

Once simazine has been applied to the soil surface, no hoeing or cultivation must take place until it is quite clear from the growth of the weeds that the herbicide has disappeared. Individual established weeds, overlooked at the time of spraying, should be removed by hand, taking care to disturb the soil as little as possible. If the soil surface is beaten down in heavy rain and forms a cap or "skin" which has to be broken to permit easy penetration of water, this should be done, moving the soil as little as possible.

Simazine is slow to take effect; two to four weeks may elapse between its application and the first death of weeds.

*Precautions when applying Simazine*

Simazine is not poisonous, but care should be taken not to get simazine onto the skin as it may occasionally cause irritation. Rubber gloves should be worn when weighing out and mixing; any splashing onto arms, face or clothing should be washed off quickly.

## SEEDBED TREATMENTS

### 10.22 Pre-sowing Weed Control in Seedbeds

Seedbeds prepared several weeks before the expected date of sowing may produce a crop of weeds. Such beds may be sprayed before sowing with vaporising oil at 60 gallons per acre/*700 litres per hectare* or with paraquat at 4 pints of formulation in 40 gallons of water per acre/*5 litres in 400 litres per hectare.*

### 10.23 Pre-emergence Weed Control in Seedbeds

*Mineral Oils in Pre-emergence Control*

Pre-emergence sprays may be applied at the rate of 60 gallons of vaporising oil per acre/*700 litres per hectare* up to three to four days before the tree seedlings emerge above the ground. It is safe to spray at any time prior to this date and spraying is recommended as soon as sufficient weeds have germinated to warrant control. The expected date of emergence can be estimated by uncovering and examining a few seeds in the seedbed. If the seeds are found to have radicles about half an inch/*1 cm* long, seedlings can be expected to emerge in about three days (slightly later for the large-seeded hardwood species). Alternatively if on a close examination of a *large* seedbed no more than *one or two* emerged seedlings can be seen, emergence of the remainder will start in three to four days. In either circumstance, a spray can still safely be applied provided this is done without delay. If the crop seedlings are not about to germinate, the state of the weed crop should determine when to spray. If many weeds are expected to emerge after an interval of one or two days, it is worth while delaying the spray. If in doubt, spray at the earlier rather than at the later opportunity.

If the emergence of the tree seedlings is delayed and more weeds appear after the first flush has been killed by spraying, there is no danger in giving a second spray (provided, of course, that the tree seedlings are not going to emerge for three to four days).

Pre-emergence sprays of vaporising oil at the recommended rate and time of application are safe for all conifer and hardwood species. They have been regularly applied in most Forestry Commission and privately-owned nurseries and have saved much time. In the last few years, however, paraquat has come into use as a slightly cheaper alternative to vaporising oil.

For most species, spraying with oil after seedlings have started to emerge will result in the death of the emerged seedlings. Scots and Corsican pines are exceptional and usually are able to stand up to a delayed pre-emergence spray of vaporising oil as long as the seed coat encloses most of the cotyledons.

*Paraquat in Pre-emergence Control*

Paraquat may be used as a pre-emergence spray to seedbeds, applied up to three to four days before seedling emergence at 2 pints of formulation in 40 gallons of water per acre/*2.5 litres in 400 litres per hectare*.

Emergence can be predicted as described in the first paragraph of this section.

Paraquat must not be applied if seedlings have started to emerge.

*Simazine in Pre-emergence Control*

Hardwood seedbeds where the seed is covered after sowing with one or more inches of soil (i.e. oak, beech, chestnut) may be sprayed with 4 lb simazine (50 per cent powder) in 60 gallons of water per acre/*4.5 kg in 600 litres per hectare* before emergence of the seedlings.

Conifer seedbeds must not be treated with simazine before emergence.

### 10.24 Post-emergence Weed Control in Seedbeds

*Mineral Oils in Post-emergence Control*

In the period from the beginning of emergence of tree seedlings until four weeks after all the germinating seedlings have emerged, mineral oil sprays must not be applied. (As outlined in the preceding section, Corsican and Scots pines can tolerate early post-emergence sprays as long as all the cotyledons and first leaves are protected by the seed coat, and exceptionally may be sprayed shortly after emergence).

After four weeks have elapsed from completion of germination, seedbeds may be sprayed as follows:

(*a*) Scots and Corsican pines, Norway and Sitka spruce, Western red cedar and Lawson cypress may be sprayed with white spirit at 25 gallons per acre/*275 litres per hectare*.

(*b*) Lodgepole pine, larches, Douglas fir, Western hemlock and *Abies* species are only moderately resistant to oil sprays and should be sprayed at rates of 15 gallons of white spirit per acre/*165 litres per hectare*.

White spirit sprays may be repeated at intervals of three to four weeks. White spirit is *only* effective against very small weeds, i.e. when in the cotyledon or first true-leaf stage. There is little point in spraying at the recommended rates on seedbeds full of large well-established weeds; such plants may be checked slightly but that is all. To be killed, they *must* be sprayed when small.

Hardwoods must not be sprayed with any oil, nor must vaporising oils be used as post-emergence sprays.

Conifer seedbeds in the second year should be sprayed at the same rates as for post-emergence sprays to first year beds, but treating bud-break as germination, i.e. not spraying within four weeks after buds break. Beds may also be sprayed as for post-emergence sprays before bud-break.

*Paraquat in relation to Post-emergence Control*

Paraquat must *never* be used after crop seedlings have emerged. Initially, it will appear as though a good kill of weeds has been obtained with no damage to the crop. However, crop seedlings only develop symptoms two to three weeks after spraying and most of them ultimately die.

*Simazine in Post-emergence Control*

Second-year seedbeds of all species except Japanese larch, ash and *Picea omorika* may be treated with simazine at 2 lb of 50 per cent wettable powder in 40 gallons of water per acre/*2 kg in 400 litres per hectare* provided seedlings are more than 2 in/*5 cm* tall. Undercut seedbeds should not be sprayed

First year conifer seedbeds must *not* be sprayed.

## TRANSPLANT LINE TREATMENTS

### 10.25 Weed Control in Lines

*Mineral Oils on Transplant Lines*

Sprays of vaporising oil or white spirit may be applied *between* rows of conifer transplants. It is important to minimise the amount of spray reaching young rapidly growing stems and foliage of the transplants as these may be scorched and checked in growth. There have been a number of instances where plants have suffered browning of foliage and check as a direct result of mis-directed spray or serious drift of spray droplets, but such checks have usually had no serious effect on yield and growth, plants generally having recovered by the end of the season.

Table 31 below gives rates of oils which can safely be applied.

*Paraquat and Paraquat/Diquat mixtures on Transplant Lines*

Paraquat and mixtures of paraquat and diquat will kill any foliage or bark of transplants they contact. They can only be safely used in transplants if applied by a dribble-bar fitted with shields which deflect foliage from the path of the dribble-bar. They should be applied at 2 pints of liquid concentrate in 40 gallons of water per acre/*2.5 litres in 400 litres per hectare*. (Plate 25).

*Simazine on Transplant Lines*

Simazine may be applied at 4 lb per acre of 50 per cent wettable powder (the formulation normally available) in 60 gallons of water per acre/*4.5 kg in 600 litres per hectare* to ground carrying transplants of all the commonly grown species except European larch, *Picea omorika*, ash and poplars. Plants must be more than two inches/*5 cm* high at the time of spraying.

Simazine may be applied at 2 lb of 50 per cent powder per acre in 60 gallons of water/*2 kg in 600 litres per hectare* to ground growing European larch and *Picea omorika* transplants, these species being less tolerant of simazine than other conifer species.

Simazine must not be applied where ash transplants are growing or where poplar cuttings have been inserted.

The symptoms of simazine damage are a yellowing or browning of the needles starting at the tips, or a marginal yellowing or browning of the leaves of hardwoods. If current shoots of conifers are affected, needles may be checked in growth and fail to reach full size, even though in no way mis-shapen. Symptoms may appear between two and six weeks after spraying. Trees damaged, but not killed, put out healthy, full size foliage later in the season. There is no distortion of shoots.

Whenever simazine is applied, the ground must be clean. Best results are obtained when the surface of the ground is moist at the time of spraying and rain falls within a day or so afterwards.

*Simazine Application to Transplants in Winter and Spring*

Ground newly lined-out with transplants may be sprayed at any time when the ground is moist, from time of lining-out until the end of May. Simazine

TABLE 31

SEASONAL MAXIMUM RATES OF VAPORISING OILS AND WHITE SPIRIT FOR WEED CONTROL IN TRANSPLANT LINES

| Season | Species | Vaporising Oils | | White Spirit | |
|---|---|---|---|---|---|
| | | *Rate per hectare* | Rate per acre | *Rate per hectare* | Rate per acre |
| After flushing and before the end of June | Douglas fir and larches | *Unsafe* | | *165 litres* | 15 gall |
| | Common pines and spruces | *Unsafe* | | *275 litres* | 25 gall |
| | Broadleaved species | *Unsafe* | | *Unsafe* | |
| Early July to late September | Douglas fir and larches | *Unsafe* | | *275 litres* | 25 gall |
| | Common pines and spruces | *275 litres* | 25 gall | *330 litres* | 30 gall |
| | Broadleaved species | *Unsafe* | | *Unsafe* | |
| Autumn, winter and early spring | Douglas fir | *Unsafe* | | *Unsafe* | |
| | Broadleaved species and larches | *275 litres* | 25 gall | Not recommended on account of expense | |

may be put on within a few days of transplanting, though it is preferable to delay the treatment of ground lined-out in late autumn or early winter until just before weeds start to germinate.

Simazine applied before the end of May can be expected to have disappeared by late September, so that there is no need to fear residues, should plants have to be lined out on the ground in the autumn following application.

*Simazine Application to Transplants in Summer and Autumn*

Simazine may be applied in the summer (June–August) only on ground which will not have a new crop lined out, or seed sown, before the late winter or early spring following.

After August, simazine should only be applied where transplants are going to remain *in situ* for another growing season.

A second application in the same season should only be given after at least four months have elapsed since the preceding application, when it is clear that young weeds have recently germinated and become established. The presence of a few old large and well-established weeds is no safe indication that simazine has disappeared. Shortly before any second application, the ground should be cultivated to kill the young weed crop. If a second application is not made but ground has become weedy, the weeds may be controlled by light cultivations.

*Method of Application for Simazine*

Apply as an inter-row or overall spray. There is no risk of simazine causing scorch of foliage; however, every effort should be made to apply it to the soil rather than waste it on foliage. There is no objection to the spray striking the bottom of the stems of transplants, but it is essential to avoid overlap of spray swathes and consequent double dosage especially if this is likely to occur near the stems of plants.

Simazine remains as a powder suspended in water. Make up the simazine/water spray mixture just before use. If a sprayer containing any simazine/water mixture is left standing for any time, some of the powder will settle out and the spray may be ineffective.

Simazine clogs filters on certain makes of tractor-mounted spray boom. Where this occurs, the filters should be removed before spraying.

## TREATMENTS FOR WASTE LAND AND PATHS

### 10.26 Weed Control on Fallow and Waste-Land and Permanent Paths

The best way of controlling newly germinating weeds on fallow land is by regular cultivation (see Section 10.3). Herbicides are effective but more expensive. On permanent paths, etc, chemicals are usually the only possibility.

*Paraquat and Diquat on Waste, Paths and Fallow*

Weeds on paths and waste-land may be sprayed with paraquat or paraquat/diquat mixture at 4 pints in 40 to 60 gallons per acre/*5 litres in 400 to 600 litres per hectare.* The top growth of such weeds will be killed but perennials with persistent underground roots and rhizomes are likely to survive and sprout again.

Normally, it is cheaper to cultivate fallow land than to spray. However, in very wet periods when tractor-powered machinery cannot get onto the land, individual large weeds can be killed by spot-spraying, applying paraquat by itself or in a mixture by knapsack sprayer.

*Simazine on Waste-Land and Paths*

Simazine can also be used to control weeds on paths and waste-land. For these types of ground, it should be applied at 10 to 15 lb of 50 per cent wettable powder per acre in 40 to 60 gallons of water/*10 to 15 kg in 400 to 600 litres per hectare.* For any waste-land where machinery can be used, however, it will be cheaper to control weeds by repeated light cultivation.

### 10.3 Mechanical Control of Weeds

Implements which uproot or sever weeds are mainly used in transplant lines and on fallow ground. They can also be used between drills in drill-sown seedbeds though only a small proportion of nurseries sow in this way.

Where implements are mounted on a tractor tool bar so that several inter-row strips can be cultivated simultaneously, it is essential that the spacing between rows of transplants, or between drills, be constant. This can be achieved by care at lining out, the position of the trench for each line of plants being carefully determined so as to avoid any cumulative error in the position of the line.

Where a lining-out plough is used, the tractor driver's skill determines how evenly and accurately lines are spaced out.

Implements for weed-control can be grouped into scarifiers, hoes and ploughs or cultivators.

**10.31 Scarifying Implements.** Plate 22

Light scarifying or cultivating tines can be used for the inter-row control of weeds. These consist of vertical tines which run in groups of three or more between each two rows of plants. The tines are usually mounted on a tool-bar and are lightly sprung so that they can vibrate easily. In use, they continuously agitate the soil in a band extending ½ to 1 inch/*1.5 to 2.5 cm* either side of each tine. Such implements are most effective used on light soils at intervals of two to three weeks, i.e. when the weeds are small; they are less effective on heavy soils and cannot deal with large well-established weeds. Generally a little handweeding is required in conjunction with the tines, to eliminate weeds growing in the actual rows between plants.

### 10.32 Hoeing Implements

These all slice the soil horizontally just below the surface, severing big weeds and uprooting small ones. There are rotary cultivators, reciprocating hoes and fixed hoes. All can tackle weeds of any size on any soil, but ideally any one should be used sufficiently frequently in conjunction with other means of weed control so that no large weeds are ever allowed to develop. If carelessly used, mechanical hoes can damage roots and side shoots of seedlings and transplants to a far greater extent than the tine weeders. Fixed hoe blades attached to a tractor tool bar, are generally less satisfactory than rotary or reciprocating hoes, as they tend to ridge up the soil against the bases of the transplants, smothering the lower foliage. Rotary and reciprocating hoe blades move much faster in relation to the soil, and leave the disturbed soil more or less in place.

### 10.33 Ploughing and Cultivating Implements

These are suitable for controlling weeds only on fallow ground, and act by burying weeds. Normal agricultural ploughs can be used, and if used

TABLE 32

THE EFFECT OF FREQUENCY OF WEEDING ON TIME OF WEEDING

| Year of Expt. | Interval between successive weedings Weeks | Number of weeds removed per square yard* (Total for season) | | Total (accumulated) weeding time for whole growing season Minutes per sq yd* | |
|---|---|---|---|---|---|
| 1957 | | Bramshill | | Bramshill | — |
| | 2 | Not assessed | | 7.7 | |
| | 4 | | | 7.4 | |
| | 6 | | | 12.9 | |
| 1958 | | Bramshill | Ampthill | Bramshill | Ampthill |
| | 2 | 110 | 56 | 9.1 | 9.6 |
| | 4 | 98 | 61 | 7.3 | 8.1 |
| | 8 | 166 | 256 | 12.1 | 20.3 |
| 1959 | | Bramshill | Kennington | Bramshill | Kennington |
| | 1½ | 27 | 57 | 0.9 | 4.6 |
| | 3 | 31 | 52 | 1.2 | 4.4 |
| | 6 | 55 | 84 | 1.7 | 6.5 |
| | 12 | 541 | 1 068 | 15.3 | 30.7 |
| 1960 | | Bramshill | Kennington | Bramshill | Kennington |
| | 1½ | 40 | 79 | 2.3 | 4.8 |
| | 3 | 34 | 86 | 1.9 | 5.4 |
| | 6 | 53 | 154 | 3.3 | 8.6 |
| | 12 | 346 | 198 | 15.4 | 12.7 |

*For numbers of weeds or weeding times per sq m, multiply figures in table by 1.2.

*Notes: Bramshill* nursery has a sandy soil, pH 4.5. The section used was opened in 1943 and has a weed population dominated by *Poa annua* and *Spergula arvensis*.
*Ampthill* nursery soil is a loamy sand, pH 6.0–6.5; the nursery was opened in 1920. The most common weeds are *Poa annua*, *Stellaria media* and *Senecio vulgaris*.
*Kennington* nursery has a sandy loam soil pH 5.0–5.5; the section used was opened in 1945 and has a mixed weed population including *Poa annua*, *Spergula arvensis*, *Capsella bursa-pastoris*, *Senecio vulgaris*, etc.

regularly in this way should be set to plough no deeper than 3 to 4 inches/*10 cm*, so that any "plough pan" which may be formed during the season is broken by the end-of-season ploughing at the normal depth. Rigid or heavy agricultural spring-tine cultivators mounted on a tractor tool bar cannot be used between transplant lines but may profitably be used on fallow land. They have much the same effect as shallow ploughing in turning over the surface soil and cover the ground much more quickly. They may create a shallow cultivation pan if used when the soil is wet but being shallow, this can be broken up by deep ploughing in the autumn.

### 10.34 Timing of Cultivations

Tines, hoes or ploughs should be used just as often as is necessary to prevent weeds seeding. In practice, the interval between successive cultivations may vary from one to five weeks. For example, it may be necessary in periods of warm moist weather to cultivate 7 to 10 days after a previous cultivation, especially where there are numerous big weeds; at the other extreme in periods of cold, dry weather, there may be no weed growth at all.

## 10.4 Control of Weeds by Hand

The oldest way of controlling weeds is to pull them out by hand individually. Although effective, it is generally the most expensive method, £100 to £200 per acre/*£250 to £500 per hectare* (1970 rates) being spent annually hand-weeding seedbeds in many older nurseries. Modern implements and chemicals have reduced the need for hand-weeding; nevertheless, there are still circumstances where weeds can only be controlled by hand, the most important of these being in the period during and immediately after germination of forest tree seedlings. Removal by hand also has to be resorted to where weeds are resistant to chemicals and inaccessible to implements.

When hand-weeding is necessary, it is strongly recommended that it be carried out thoroughly at intervals of three to four weeks. Hand-weeding once every six to eight weeks involves 30 to 100 per cent more work in total over the season because of the increased number of weeds removed and their greater size (Table 32).

Weeding by hand is necessarily a slow job and it is important to start any weeding as soon as the first weeds are visible, even though they may be small, so as to *complete* the task before the weeds on the last piece of ground to be reached have grown too big. And as soon as one cycle has been completed, the ground first cleaned should be scrutinised to see whether more weeds have grown and at the next cycle started. When in doubt, weed! Table 32 shows clearly that it is very little more time-consuming to weed once a fortnight, but if weeding is put off, the time required increases rapidly.

## 10.5 Other Methods of Controlling Weeds

### 10.51 Mulches

Mulches of various materials have been used on transplant lines in order to smother weeds. Materials have included hopwaste, bracken sawdust, sisalkraft paper, metal foil and 150-gauge black polythene film. Generally they have been fairly successful in controlling weeds but there are distinct practical disadvantages with all of them and none has been put into practice on any scale.

Hopwaste, bracken or sawdust mulches can reduce hand-weeding by 60 to 90 per cent and stimulate the growth of transplants, but the quantity of mulching material required for any large area is excessive. Using sawdust, a layer one or two inches thick is required, while with straw or bracken, a layer two or three inches thick is needed to be effective. A mulch two inches thick requires over 7000 cubic feet of material per acre, i.e. roughly 90 tons of mulch per acre/*225 tonnes per hectare*.

The paper, black polythene and foil mulches have been laid in strips between adjacent rows of transplants, the strips being held in position using soil, stones and pieces of builders lath. All three of these strip mulches suppress weeds in the centre of the strip, but the weeds grow out from under the edge of the mulch strip and have to be pulled out by hand. The paper mulches curl up at the edges when wet while the foil strip tears readily. The only one that is reasonably easy to handle, and can remain intact for the whole season, is black polythene strip. However, it is quite expensive to use, if the cost of its purchase, the cost of putting it down and the cost of removing by hand those weeds growing from under the strip, are taken into account, so that the technique is no less expensive than weeding using the more conventional chemical and mechanical methods of control.

### 10.52 Soil Partial Sterilants and Fumigants

A number of materials used primarily to control soil pathogens also control weeds to a considerable extent. Edwards (1952) showed that formalin applied as a drench at 0.1 gallon per square yard/*0.05 litres per sq m* reduced the weeding time by 16 to 64 per cent. Similar effects have been observed using steam, chloropicrin and allyl alcohol. However, all such treatments are expensive (£200 to £400 per acre/*£500 to £1000 per hectare* at 1970 rates) for materials and labour of application and there is no economic justification for using them solely to reduce the time spent on weed control. See also 'Dazomet', Sec 7.64.

### 10.6 Control of Specific Perennial Weeds

#### 10.61 Agropyron repens (Couch Grass and Agrostis spp, Bent Grasses)

*Agropyron repens* can be distinguished from the rhizomatous species of *Agrostis* with which it is sometimes confused, by the presence of auricles (small pointed projections at the base of the leaf blades) which often clasp the stem, by hairs on the upper side of the leaves, and by the distinctive flowering head. The latter resembles that of perennial ryegrass except that the spikelets are set with the flat face opposing the stem; it is quite unlike the much-branched flowering head of *Agrostis* species.

The species of *Agrostis* which are particularly troublesome as weeds are *Agrostis gigantea*, which has underground creeping stems, and *Agrostis stolonifera* which has surface-creeping stems. *Agrostis canina* and *Agrostis tenuis* which may have short rhizomes are less important. The methods of control for all these grasses are similar. (See also M.A.F.F. Advisory Leaflet No. 89).

*Control of Perennial Grasses by Cultivation*

The control of rhizomatous weed grasses had, until about 1955, been dependent on using the plough, cultivator or harrow during the summer fallow. Ploughing and harrowing remain effective in a dry season but are liable to fail when wet weather persists. In wet years, rotary cultivations may be more successful. The first cultivation must be deep, slow and thorough, to ensure maximum fragmentation. The second, which can be carried out more rapidly, must take place soon after new shoots have appeared above the ground. A further cultivation should take place as soon as re-growth occurs again and the process then be repeated until all the grass has been killed. Rhizomes die either from desciccation on the soil surface or from exhaustion of food reserves; the latter only happens if new roots are unable to become established, hence the importance of frequent cultivation. The most common faults resulting in lack of control are too long an interval between successive cultivations and failure to persist in the treatment until *all* fragments are dead.

*Chemical Control of Perennial Grasses*

Herbicides available for controlling couch are dalapon, aminotriazole, TCA and dalapon. All markedly reduce an infestation of couch if used as recommended. However, complete eradication cannot be expected from a single chemical treatment. For best results, the use of herbicides must be linked with timely cultivation.

*Dalapon*

Dalapon should be sprayed onto the foliage of actively growing couch grass, when rain is not expected for at least 12 hours. Cultivation before treatment may assist by breaking up the rhizomes, but it is essential to allow sufficient time to elapse between cultivation and spraying, for a good cover of foliage to develop. Cultivation after spraying should be in the form of efficient ploughing carried out as deeply as possible, allowing a minimum interval of two weeks between spraying and ploughing.

The dose required to kill all the rhizomes may be as little as 6 lb of dalapon per acre, or as much as 40 lb/*6 to 40 kg per hectare*, according to conditions which have not yet been fully elucidated. A low dose is most likely to be sufficient in much-cultivated arable fields where the rhizomes have been broken and where treatment is followed by sowing a "smother" crop, (e.g. a green crop). A high dose of 20 lb of dalapon per acre/*20 kg per hectare* or more is likely to be required where eradication of an old-established stand of couch grass is required. A dose of 15 lb of dalapon in 60 gallons of water per acre/*17 kg in 600 litres per hectare* is recommended for the control of couch on cultivated forest nursery ground. If not incorporated in the formulation, a wetting agent should be added at the rate of 1 pint to 60 gallons/*1 litre in 600 litres*.

Dalapon may be applied to couch until the end of October provided the weed is growing actively. Normal cropping can take place the following spring, three months after application.

*Aminotriazole*

Aminotriazole is applied in a similar manner to dalapon for the control of couch and other perennial grass weeds, but its effect differs in two ways: it persists in the soil for a much shorter time than dalapon, so that crops can be sown without fear of damage sooner after spraying. Also, aminotriazole is much less selective than dalapon, giving the advantage that other weeds besides the couch may be controlled.

Aminotriazole is supplied in non-activated or activated formulations. The latter, which contain ammonium thiocyanate as activator, are more effective on certain grass species, including *Agropyron repens*. For the control of couch grass in forest nurseries, 6 lb per acre/*7 kg per hectare* of an activated formulation is recommended.

*Sodium Chlorate*

For the control of *Agropyron repens* in fallow land, sodium chlorate can be used as an early autumn application at 2 cwt per acre/*250 kg per hectare*.

The ground may be used for seedbeds or transplants 6 months after treatment, but not before then. Sodium chlorate is less reliable than dalapon or TCA.

*TCA (Trichloroacetic acid—usually formulated as the sodium or ammonium salt)*

TCA can be used to control *Agropyron repens*, *Agrostis stolonifera* (creeping bent grass) and with less certainty *Arrhenatherum elatius* (onion couch). The chemical is highly soluble and may be rapidly leached from light sandy soils; it is therefore best to treat couch on these soils in the spring or early summer, either with one dose of 30 lb per acre/*35 kg per hectare* or with two treatments each at 15 lb per acre/*17 kg per hectare*, separated by an interval of 4 to 6 weeks. Normally TCA should be applied in 60 to 100 gallons of water per acre/*600 to 1000 litres per hectare*, but if it is well distributed on a moist soil surface, as little as 20 gallons of water per acre/*200 litres per hectare* can be used. Spring and summer treatments can be followed by normal cropping in the following spring. Shallow ploughing or cultivation should precede each application in order to bring rhizomes near the surface. After spraying, light cultivations help to exhaust rhizomes and enhance the effect of the chemical.

**10.62 Calystegia sepium (Greater Bindweed, Bellbine)**

This weed is seldom found in conifer nurseries, but has locally been an important weed where established poplar stools are grown for the production of cutting material; here the bindweed may form a continuous carpet between stools and also climb up the newly-formed poplar shoots. In this situation, the butoxy-ethyl ester of 2, 4-D (or other ester of low volatility) can be used successfully, making two applications of $1\frac{1}{2}$ lb acid equivalent per acre/*1.5 kg per hectare*. The first should be put on in late May or early June to the foliage of the bindweed before it starts flowering; the second is applied to new growth in mid- or late July. Great care must be taken not to let the spray come into contact with the poplar shoots or with the poplar stools themselves. This is best achieved using a hooded jet and a low spraying pressure. The treatment does not give complete control, as there are usually a number of weed shoots which are protected by their proximity to the poplar stools. Nevertheless, if these are removed by hand early in the year and the areas are treated in the same way for two or three years, the bindweed will ultimately be eliminated. There will inevitably be some damage to the poplar stools but if spraying is done carefully, this will not be important.

**10.63 Rumex acetosella (Sheep's Sorrel)**

This weed is commonly found in acid sandy soils, though it can also thrive in cultivated ground on more fertile sites. Neither of the measures suitable for selective control in agricultural crops (liming or application of MCPA or 2, 4-D) can be recommended for forest nurseries. The only course in a forest nursery where this weed is established is to clean the ground during the fallow year by cultivation and harrowing, repeated at 2 to 3 week intervals, or by sodium chlorate applied in late summer at 2 cwt per acre/*250 kg per hectare*. Seedbeds may be sown or transplants lined out six months after chlorate treatment.

## 10.7 Spray Equipment

In selecting equipment for spraying, it is not sufficient merely to choose knapsacks or tractor sprayers of the appropriate capacity; it is also essential to have the necessary accessories such as pressure regulating valves, lances, shields, etc to permit the application of uniform and controlled amounts of spray exactly where and when required.

**10.71 Tractor-Mounted Sprayers.** Plates 23 and 24

These consist essentially of a tank, pump, spray-bar, filters and nozzles together with regulator to control the flow and the pressure. Sprayers are available in many sizes but those most suitable for forest nursery work are the "low/medium volume" sprayers, able to deliver up to 60 gallons of liquid per acre/*700 litre per hectare* at pressures of 20 to 25 lb per square inch/*1.4 to 1.75 kg per sq cm* and with tank capacities of 40 gallons/*200 litres* or more.

*Pumps* fitted to such sprayers are usually of one of two designs, gear pumps or roller-vane pumps. Both types of pump are liable to wear if abrasive materials are used, but the rollers in the latter are far more cheaply replaced than gears of a gear pump.

Two types of *spray-bar* are required for forest nursery use. For application of overall sprays such as vaporising oil, a 15 ft/*4.5 m* spray-boom able to cover three beds should be selected, the two outer sections of the boom being hinged for ease of movement through gates (Plate 23). The jets on such a boom should be 18 inches/*45 cm* above the bed surface and 18 inches/*45 cm* apart along the boom.

For inter-row spraying of transplants, a smaller boom is required which can be fitted under the belly of the tractor or at the rear. In either case, the jets should be 8 to 9 inches/*20 to 22 cm* from the point of impact of the spray on the soil surface. In the case of the belly-mounted boom, this is achieved by setting the jets to spray back at an angle of about 35° below horizontal, the jet being about 5 inches/*12 cm* above the surface of the soil (Plate 24).

The *spray tank* is usually designed to fit onto the hydraulic lift of a tractor. Some tanks are light and are easily replaceable if corroded, while others are robust and form the chassis on which the other components are mounted. Whatever the tank, there must be means of agitating the contents so that the materials are kept well mixed. This is especially important where dispersible powders (e.g. simazine), are suspended in the spray liquid. For such materials, a good means of agitation is by paddles rotating in the spray tank. A satisfactory alternative is hydraulic agitation brought about by return of liquid from the pump, provided that a sufficient quantity of liquid is returned to impart a vigorous swirling motion to the contents of the tank. It is much easier to clean the tank if it has a large inspection plate.

*Filters* to pick up dirt and extraneous matter are essential for the protection of the pump and to prevent jets from blocking. There are usually two sets, one between the tank and pump and one between the pump and spray jet either in the main feed or in the nozzles.

### 10.72 Interchangeable Equipment

Where a spray programme in the nursery and forest required regular use both of growth regulating herbicides and of contact or residual materials, it is strongly recommended that a set of hoses and containers be kept specifically for the growth regulators so as to minimise the risk of contamination.

### 10.73 Knapsack Sprayers

These sprayers range in capacity from 2 to 4 gallons/*9 to 18 litres*. There are three main types, pneumatic knapsacks in which the outer container is airtight and capable of withstanding internal pressures of 80 to 120 lb per square inch/*5 to 8 kg per sq cm*, those in which the outer tank is not under pressure but which contain an inner small reservoir which is kept under pressure by pumping as spraying proceeds, and thirdly there are those knapsacks which are solely containers and which empty by force of gravity (Plate 25).

### 10.74 Pressure Regulating Valve

This is an essential accessory for all equipment used for the application of weedkillers, whether it be a tractor-mounted sprayer (when such a valve is normally fitted at time of manufacture) or a knapsack sprayer. The valve regulates the output of spray to the nozzles and is usually fitted near the outlets from the pump or tank. Most patterns of valve can be set to spray at whatever working pressure is required, but some knapsack pressure-regulating valves are pre-set by the manufacturer to a specified pressure and cannot be altered without being returned to the factory. As long as one type of jets is used, either a pre-set or adjustable regulating valve is equally suitable.

For the application of Bordeaux mixture and other materials which contain a considerable amount of solid material in suspension, pressure regulating valves should not be used as they may become clogged by the solids.

### 10.75 Nozzles

There are two main types of nozzle or jet, one producing a flat fan and the other a hollow cone of spray respectively. Ceramic fan nozzles are designed to work at a pressure of about 30 lb per square inch/*2 kg per sq cm*, and to deliver 20 to 60 gallons of liquid per acre/*200 to 700 litres per hectare;* they are well suited for work in forest nurseries. The spray from this type of nozzle carries further than that from a hollow cone nozzle of similar output. However, some cone nozzles operate effectively at 15 to 20 lb per square inch/*1 to 1.4 kg per sq cm* and are less likely to give rise to drift.

Several sizes of jet are available; a full range of rates of application can be obtained by proper selection of nozzle size and spraying pressure.

The performance of nozzles is covered by the specification of British Standard 2968: 1958. Nozzles made in conformity with this specification can be expected to vary in output by not more than 10 per cent for discharge rates of up to 30 gallons/*135 litres* per hour, and by not more than 5 per cent for discharge rates of over 30 gallons/*135 litres* per hour. The spray angle of such jets is 65° (or 80° for wide angle jets) with a tolerance of $\pm$ 3°.

"Dribble-bars" operate at 1 to 2 lb pressure and give rise to no drift at all. The cover from such a bar is in the pattern of a series of parallel lines; this pattern is not suitable when using simazine or when many small weeds have to be killed.

### 10.76 Spray Pressure

Output from a nozzle is proportional to the square-root of the pressure. An increase in pressure will also result in a decrease of the average droplet size and so increase the danger of drift.

In forest nurseries, the spraying pressure should never exceed 40 lb per square inch/*2.8 kg per sq cm.*

### 10.77 Calibration and Control of Rates of Application

With the tractor-mounted equipment, information on the correct combination of jet sizes and spacing, working pressure and ground speed of tractor for a given rate of spray application, are supplied by the manufacturer.

The rate of delivery of knapsack sprayers fitted with a pressure regulating valve can be found by measuring carefully the amount of liquid passing through any selected jet during the period of a minute at any desired setting of the regulating valve. This measurement should be repeated three times, once when the knapsack is nearly full, once when it is half-full, and once when nearly empty, and the average delivery should then be worked out and used as the basis for the main calculation. From the average delivery per minute, it is easy to calculate the area to be covered, especially if it is remembered that one millilitre of liquid per square yard is approximately equal to one gallon per acre/*1 ml per sq m = 10 litres per hectare.* For example, to spray at 40 gallons per acre (40 mls per square yard), where one jet is delivering 500 ml per minute, the jet must cover with spray 12½ square yards (i.e. 500 ÷ 40) per minute.

Knapsacks with a pressurised container, but without a pressure regulating valve, will deliver their contents when full at twice or more the rate of delivery when nearly empty, unless the pressure is raised by pumping at intervals while the tank is emptying. For best results, such knapsacks should be pumped up to about 50 lb per square inch/*3.5 kg per sq cm* when full, and should be pumped up to this pressure again when they have discharged a quarter, half and three-quarters of their contents. This is tedious but is the only way of ensuring a reasonably steady rate of delivery.

Knapsacks which need pumping continually while spraying, must have a pressure gauge fitted on the lance. While spraying, the operator has to pump just sufficiently to keep the pressure steady and at the desired figure.

### 10.78 Cleaning Spray Equipment (Knapsacks and Tractor-Mounted Sprayers)

Failure to make certain that spraying machines are thoroughly washed out after use can lead to serious trouble. Damage to susceptible crops has sometimes been attributed to spray drift when the real cause has been the failure to clean out the residues from the previous operation.

*Cleaning Routine*

After spraying with a weedkiller suspended or dissolved in water, for example, simazine, or salt formulations of growth regulator herbicides, the machine should first be washed through thoroughly by filling with a solution of a domestic detergent. Then, the inside of the tank, its top and lid should be scrubbed as far as this is possible, and the solution be circulated through the pump and back into the tank. After this, the sprayer should be washed through twice more, and if possible the machine (and particularly rubber hose-lines) should stand over-night completely full of water containing detergent.

After spraying growth-regulating weedkillers dissolved in oil, or weedkillers formulated in an emulsion which is diluted with water, the tank should be filled with vaporizing oil or diesel oil to a depth of 6 inches/*15 cm.* This should then be circulated through the pump. Either a mop or a scrubbing brush should be used to wash down the sides and top of the tank inside with the oil, which should then be sprayed out through the pipe-lines. The procedure thereafter is the same as is described above for water-soluble weedkillers, i.e. use a detergent or similar preparation and plenty of water.

As this method of cleaning also removes oil and grease, it is advisable to re-grease parts that should be kept lubricated.

Where a detergent has been used, there should always be a final thorough wash through with plain water. This will remove any detergent which might otherwise reduce the selectivity of the next herbicide to be used.

Cleaning materials other than detergents or mineral oils are not recommended; some, e.g. permanganate, may remove the smell of the weed-killers without affecting the active principle, thus giving a misleading impression of cleanliness.

The spray equipment should normally be cleaned each night before being put away. However, if it is *certain* that spraying of the same material is to continue the following day, the sprayer need only be filled with clean water, emptied by spraying out, refilled with clean water and left to stand over-night. This will prevent any chemical, left adhering to the walls, from drying and flaking-off, and thus blocking the nozzles.

Whenever cleaning a sprayer, great care must be taken to ensure that the liquids used for cleaning are allowed to soak into waste ground where they can do no harm; alternatively, waste oils may be burnt.

## 10.8 Conclusion

This is perhaps inappropriate as a heading for a final paragraph, for there is no conclusion to weed control; it is a continuing and endless task. It is certain, however, that the immense advances in chemical weedkillers in the last fifteen years have made it possible for nurseries to be kept clean far more easily than in the past. What further advances will come are difficult to predict in detail but it will be most surprising if new materials are not developed which will help the nurseryman still more to keep down his weeding costs and so produce the best quality plants cheaply.

FURTHER READING

ALDHOUS, J. R., 1961. Experiments in handweeding conifer seedbeds in forest nurseries. *Weed Research* Vol. 1, 59–67.

ALDHOUS, J. R., 1962. Simazine—a weedkiller for forest nurseries. *Report on Forest Research*, 1961, 154–165.

ALDHOUS, J. R., 1966. *Simazine residues in two forest nursery soils.* Research and Development Paper No. 31. Forestry Commission.

ALDHOUS, J. R., 1966. Paraquat as a pre-emergence spray for conifer seedbeds. *Report on Forest Research*, 1965, 133–140.

ANON., 1961. *Farm Sprayers and their use.* Bulletin No. 182, Ministry of Agriculture, Fisheries and Food.

ANON., 1968. *Couch or Twitch.* Ministry of Agriculture, Fisheries and Food. Leaflet No. 89.

CHANCELLOR, R. J., *Identification of seedlings of common weeds.* Bulletin No. 179, Ministry of Agriculture, Fisheries and Food.

EDWARDS, M. V., 1952. *The effects of partial soil sterilization with formalin on the raising of Sitka spruce and other conifer seedlings.* Forest Record No. 16, Forestry Commission.

FRYER, J. D., editor, *Weed control handbook.* Vol. I, 5th edn., 1968; Vol. II, 7th edn., 1972. Oxford, Blackwell's Scientific Publications.

*See also:*

APPENDIX V. Observations on the response of Annual Meadow Grass and some other common weeds to soil pH, page 153.

# Chapter 11

# PROTECTION AGAINST CLIMATIC DAMAGE, FUNGI, INSECTS AND ANIMALS

Forest nurserymen are fortunate in not needing to combat fungi, insects or climatic damage as part of any automatic routine. Each of these agencies can on occasion be devastating, but only in a few nurseries does any particular type of damage occur regularly and call for the appropriate counter-measures each year. Some diseases are widespread and sometimes serious, especially Damping-off and Grey mould (*Botrytis*); however, their incidence is capricious and can seldom be forecast.

Two useful text books are available providing information on forest pests. The *Insecticide and Fungicide Handbook*, 2nd Edition, 1969, contains sections on these materials in relation to forest nursery and forest pests, while *Pathology of Trees and Shrubs* (Peace, 1962) contains excellent discussions and descriptions of damage due to cold and heat, water-logging and drought, a chapter on nursery diseases and full discussions of other diseases which may occur on trees both in the nursery and plantation. There are also various Forestry Commission Leaflets describing the more important fungi and insects and their effect on the young trees and outlining their general biology. These are listed at the end of this chapter.

Some of the materials recommended below are very effective but may also be unpleasant or even dangerous if mishandled. Before using any pesticide:

**always read the label on the container: observe precautions scrupulously and ensure that your employees do so too.**

Keep pesticide concentrates as far as possible in their original containers. If it is necessary to transfer some to another container, ensure that this is effectively and fully labelled. On no account use bottles which have contained orange squash, milk or other foodstuffs.

## 11.1 Climatic Factors

### 11.11 Low Temperatures

Plants may be subjected to temperatures below freezing at almost any time of the year. Peace (1962) shows how in an average year the ability of trees to resist freezing changes rapidly in the autumn and spring and that it is only in December and January that plants are able to withstand the severest frosts. There is also a great deal of variation in frost susceptibility between species and often between provenances or varieties of a species.

Generally, forest nursery stocks are not protected from frosts. If protection is to be given, lath shelters are the most widely used and convenient form.

Standard lath shelters are made of builders laths, 4 feet or 4½ feet/*1.3 m* long and tied together with wire so that they can be unrolled over beds. Some support is required to keep the laths off the ground and this is usually provided by two strands of No. 8 or No. 10 fence wire stapled to the tops of short stakes projecting 12 to 18 inches/*30 to 45 cm* above the bed and with straining posts at each end of the bed to enable the wire to be pulled tight.

Alternatively rigid frames of laths, rolls of chestnut paling and heavy camouflage netting may be spread over beds; rows of branches obtained during brashing operations in the forest have also been laid over the surface of beds. However, these alternatives are either heavier, more expensive or less easily handled than lath shelters.

The denser the cover the greater the protection afforded, especially against radiation frost.

### 11.12 Winter Cold

Exceptionally low winter temperatures, particularly if these alternate with mild spells or are accompanied by strong winds, can cause severe damage to many species, especially Western hemlock, Lawson cypress and Western red cedar.

Damage can also occur when low temperatures coincide with strong winds and bright sunshine. See Section 11.3.

Such forms of damage occur only once or twice a decade; usually it is not worthwhile to erect shelters to avert the worst effects.

### 11.13 Frost-lift. Plate 16

Severe or prolonged frost can cause wet or heavy soil to lift or heave. This is brought about by the formation of ice crystals which lift up the surface soil, together with any weakly-rooted plants; later, as the ice melts, the soil falls away and leaves the young plants half out of the ground. If the process is repeated, plants may be completely uprooted or frost-lifted. In the past, when much seed was sown on the heavier soils, frost-lift brought about heavy losses of small one-year old seedlings scheduled to stand in the ground for a second year before lifting. However, on the well-drained sandy soils of most of present-day nurseries, frost-lift of small seedlings is very rare. Newly lined-out transplants can quite readily be lifted out of the ground by frost and on heavy soils the possibility of frost-lift may deter the nurseryman from transplanting seedlings in the autumn.

### 11.14 Late-spring Frosts

Late-spring frosts, if severe, may severely damage newly germinated seedlings and any transplants that have broken bud. Newly germinating conifer seedlings are not affected by most late-spring frosts, but in their second year conifer seedlings are as susceptible as transplants. Fortunately, in most seasons, most transplants, especially those newly lined-out, are still dormant at the time of the last severe spring frosts.

If the nursery is in a frosty locality, it is usually worth erecting lath shelters over hardwood seedbeds and any other particularly valuable and susceptible stock. The shelters should normally be kept rolled up and be rolled out over the beds only when frost is expected. For protection from frost, the closer the laths are together the better; if the wire has stretched so that the individual laths are more than 1½ inches/*4 cm* apart, it is better to apply a double layer. Such shelter will afford complete protection from a light frost, moderate protection from a severe frost, but only a little protection from an exceptionally heavy frost.

In fruit orchards, fans, fires or sprinkling with water have been tried as a means of protection against spring frosts. All these remedies except the last are out of the question in forest nurseries. Irrigation equipment has been installed in a few forest nurseries and could be used. The principle is that water is applied throughout the night when a damaging frost is expected. The latent heat of freezing of the water ensures that the temperatures do not drop much below freezing point and so the risk of damage is averted.

The most effective step to minimise both spring and autumn frost damage should have been taken when selecting the nursery site, by avoiding frost flats or hollows. However, during the life of a nursery, care must also be taken to ensure that no frost hollows develop as a consequence of growth of adjoining plantations, shelterbelts or hedges. If these do grow up and prevent cold air from draining, one or more gaps must be cut to let the air flow away. These gaps should be about as wide as the barrier is high.

Overnight spring frosts may delay the start of work the following morning. This loss of working time can be minimised by spreading lath shelters or a polythene sheet over sufficient ground to provide one or two hours work the following morning. The shelter protects the soil sufficiently to enable work to start without delay and by the time the protected soil is planted up, the unprotected soil is usually workable.

### 11.15 Early-autumn Frosts

These regularly cause damage to susceptible, late-growing species such as the redwoods (*Sequoia* and *Sequoiadendron*) and *Cryptomeria*. Douglas fir, Sitka spruce and Western hemlock may also sustain slight injury, especially the more southerly provenances of these species. Very often, plants damaged by early autumn frosts are colonised by Grey mould (*Botrytis cinerea*) and many suffer further damage on this account.

A number of experiments have investigated how far the frost susceptibility of such late-growing species as the larches or Douglas fir, or Sitka spruce could be influenced by heavy or late applications of nitrogen. All that was found was that heavy applications of nitrogen delayed the formation of winter buds by a fortnight or so. In all but one of numerous experiments over several years there was no significant increase in frosting attributable to the heavy or late application of nitrogen fertilisers. With Sitka spruce, additions of potassium markedly reduced frost damage. So also did late top-dressings of nitrogen but to a lesser extent. (See Section 5.3).

### 11.16 Sun

Heat damage brought about by sunlight raising the temperature at the soil surface is rare but is seen from time to time in the form of injury to the stem just above the soil surface.

Formerly, when it was customary to sow in late April or early May, newly-germinated seedlings were subject both to severe moisture stress and to heat damage in hot dry periods in early summer, and sheltering by laths as described in section 11.11 was essential. The recommendation was to apply shelter whenever the screen maximum temperature exceeded 70°F on two consecutive days. In recent years, however, as sowing in March or early April has become more general, sheltering is not normally required, as seedlings are more robust by the time the hot weather comes. The only species regularly sheltered are small-seeded or slow-germinating species such as Silver firs (*Abies* spp.), Western hemlock and Western red cedar. Even with these species, when seed is sown early, shelter is not essential. Shelters are inconvenient because the wires and supporting stakes needed to support the shelter also prevent the passage of machines applying pre-emergence herbicides. They are also costly to erect and manage.

The colour of the seedbed surface materially affects the temperature at the soil surface (Section 7.36, Table 25). The temperature under a very light-coloured, fine quartz grit was lower in periods of bright hot sun than under a dark grey basalt grit similar in particle size to the quartz. Up to 50 per cent fewer seedlings of Sitka spruce, Lawson cypress and Grand fir survived on the dark material than on the light one.

### 11.17 Drought

In periods of drought, seedlings and transplants suffer from acute shortage of water. In newly-germinated seedbeds, smaller shallow-rooted seedlings may wither and turn a pale straw colour. Older plants seldom die but growth usually slows down or stops; foliage of hardwood species, such as beech, may turn brown at the edges (marginal scorch).

Drought damage in nurseries is commonly associated with hot, dry weather in the summer. However, the browning of foliage following dry, strong winds in cold periods in the winter and early spring is due to drought, the plants being unable to take up water from the frozen soil or to translocate water when the stem is frozen.

The harmful effects of summer drought may be avoided by hand watering or by overhead irrigation (Section 7.5) or by shelters. See also Section 5.2—fertiliser damage.

## 11.2 Protection Against Fungi

Fungi only occasionally take a heavy toll of seedlings and rarely kill transplants. At present, routine preventative sprays are needed only in some regions and for a small proportion of the species regularly grown. Elsewhere, sprays or other treatment should be applied only as required.

**Caution:** Some fungicides may be unpleasant to handle. **Always read the label on the container before use and observe the precautions recommended.**

### 11.21 Damping-Off

Damping-off losses may commence before seedlings emerge but they are normally most obvious in the four weeks or so following germination. The typical symptoms of post-emergence attack are seedlings toppling over and signs of fungal attack on roots or at the base of the hypocotyl or both. The damage may occur in patches, spreading outwards.

Many soil-inhabiting fungi are involved, some being important in certain localities and not in others. The most important are *Pythium* species, *Rhizoctonia solani*, *Fusarium* species and *Phytophthora cactorum*. Damage is worst in warm, humid periods in early summer on late sowings.

Damping-off can be checked by a drench of "Captan," applied as soon as losses are seen. If damping off occurs regularly, however, seedbeds may be partially sterilised with formalin before sowing, as described in Section 7.14.

For a post-emergent drench, 1 lb of "Captan" 50 per cent wettable powder should be mixed with 100 gallons of water and applied at 1 gallon per square yard/*1 kg of "Captan" in 1000 litres of water at 5 litres per sq metre.* This treatment should be applied immediately damping-off symptoms are seen and should be repeated a fortnight later.

Potassium permanganate should not be used against damping-off. There is little doubt, despite claims to the contrary, that when applied to seedbeds against damping-off, the fungicidal effect is negligible and the rise in pH caused by the rapid chemical reduction of the permanganate tends to encourage the development of damping-off fungi in the soil.

Recent work indicates that a seed-borne fungus, at present un-named, can cause heavy pre-emergence losses of Sitka spruce seedlings, if cold conditions prevail for several weeks after, particularly early sowing, or if infected seed is prechilled. (Salt, 1967).

### 11.22 Grey mould

*Botrytis cinerea.* See also Forestry Commission Leaflet No. 50. This fungus is generally recognised from its grey whiskery appearance. On closer scrutiny, this can be seen to consist of a web of mycelium bearing tufts of small slender-stalked spherical spore clusters. The fungus is very widespread and readily colonises any dead and dying vegetable matter, from which it can invade adjacent healthy tissues. Spores are normally formed within a few weeks of the initial infection of weakened or dying vegetation; during the growing season spores are always available to colonise new material whenever conditions are suitable.

In the nursery, there is a considerable difference of susceptibility between species; those with a long growing period are much more liable to attack, if only because they harden off late in the autumn and are the more subject to frost damage.

Those species most regularly attacked include the *Sequoia* and *Sequoiadendron* genera, *Cupressus* species, and *Cryptomeria japonica*. Whenever these less commonly-planted species are raised, they should be sprayed regularly to minimise damage (see below for details). Tips of Sitka spruce and Douglas fir shoots also occasionally suffer from frost and may subsequently be infested. Species such as Western hemlock and Japanese larch, when grown rapidly and overcrowded in the seedbed, are subject to attack, which starts just above the soil surface on leaves weakened through lack of light and spreads to the main stems. If these main stems are girdled the tops die, thereby providing further suitable material for the fungus. In nurseries where growth is vigorous, species subject to this type of damage should be sown at densities which will not give rise to overcrowding.

Root damage through waterlogging or late damping-off may also weaken plants sufficiently for them to be attacked by *Botrytis;* where there is no other obvious reason for attack, roots should always be examined for this predisposing factor.

There is no means of curing infected trees. All that can be done is to minimise the risk of spread to uninfected plants.

Where attack by *Botrytis* is expected, or at the very first signs of attack, preventive sprays should be applied. Bordeaux mixture is the most effective and persistent. "Thiram" or "Captan" may also be used; they are less effective and persistent but are easier to apply. Whichever material is used, it should be applied at between 2 and 3 gallons per 100 square yards/*1000 to 1500 litres per hectare*, i.e. sufficient to wet all foliage thoroughly. Applications should be repeated at intervals of three to four weeks. Bordeaux mixture gives best results when freshly made from copper sulphate and hydrated lime. Both materials are available from general horticultural suppliers. A 4/4/40 mixture is recommended, i.e. 4 lb copper sulphate and 4 lb hydrated lime in 40 gallons of water/*4 kg plus 4 kg in 400 litres*. Dissolve the copper sulphate in 5 gallons of water and then add to 35 gallons of lime suspension, prepared by first making a thin paste of the lime and then adding the rest of the water. Apply at intervals of 2 to 3 weeks if necessary.

Pre-mixed Bordeaux can be obtained in small quantities as a wettable powder from horticultural suppliers. The ingredients of Bordeaux mixture, whether separate or as the pre-mixed powder, must be kept in airtight tins in a dry place until required.

Thiram should be made up as a 0.4 per cent suspension of 80 per cent wettable powder, i.e. 4 lb of powder per 100 gallons of water/*0.4 kg per 100 litres*. An anionic wetter should be added at the rate of between 1 and 5 fluid ounces per 100 gallons/ *2 to 10 ml* per 100 litres (1 fluid ounce/*2 ml* if the water is very soft, 5 fluid ounces/*10 ml* if the water is very hard).

'Captan' should be applied as a 0.2 per cent suspension of 50 per cent wettable powder, i.e. 2 lb of powder in 100 gallons of water/*0.2 kg per 100 litres* with an additional wetter as for 'Thiram.'

### 11.23 Needle cast of pine

*Lophodermium pinastri* (Schrad.) Chev. See also Forestry Commission Leaflet No. 48. This is the fungus most commonly found on needles of Scots pine. Infected needles are killed and heavily attacked plants may lose all their foliage; in seedbeds and lines this usually results in the death of the plants. Scots pine is the most susceptible species but most other pines have been attacked. The disease is most prevalent where nurseries adjoin pine plantations which act as a reservoir of inoculum for the infection of susceptible species. Control is best achieved by ensuring that there are no potential sources of infection within 100 yards/*100 metres* of the boundary of the nursery. Where this is not possible, or where experience shows that *Lophodermium* attack occurs regularly, a preventive spray should be given to susceptible species at intervals of three to four weeks, starting in late July, and using 3 lb of 'Zineb' 80 per cent wettable powder, in 100 gallons of water per acre/*3 kg of powder in 1000 litres per hectare*. If 'Zineb' is not available, Bordeaux mixture should be applied at the times recommended for 'Zineb', but at the rates as described for the control of *Botrytis* in Section 11.22.

As symptoms of attack appear only in late summer or in the autumn, there is no point in spraying after their appearance.

### 11.24 Larch Leaf-cast

*Meria laricis* Vuill. See also Forestry Commission Leaflet No. 21. Leaf-cast is a disease causing older needles to wither and die. When attack is heavy, plants may be almost completely defoliated; in these circumstances growth will be checked and the proportion of weakly plants will be increased appreciably. Although regarded as a disease generally distributed over Britain, in recent years it has been most prevalent in north and west Scotland. The disease affects European larch and occasionally Hybrid larch, but Japanese larch is resistant. It occurs where larch plantations adjoin nurseries or where seedbeds or lines have to stand in the same place for two years. The former risk can be reduced by felling the larch and replacing with another species.

Foliage infected by the fungus cannot be freed from infection. In those nurseries where attacks are experienced regularly, plants may be protected by spraying colloidal sulphur at 3 pints of colloidal sulphur in 100 gallons of water per acre/*4 kg in 1000 litres per hectare*. The spray must first be applied when plants start to break bud and should be repeated at intervals of about three weeks until early August. In early springs, or in sheltered nurseries, the first sprays may have to be applied in late February. Spraying should take place in cool, dull conditions if possible; hot sunny conditions must be avoided if scorch of foliage is to be avoided, though this, if it does occur, is less serious than the damage due to *Meria* which the spray is likely to have prevented.

### 11.25 Oak Mildew

*Microsphaera alphitoides*. See also Forestry Commission Leaflet No. 38. This disease occurs commonly on the leaves of oak, whether seedlings, transplants or older plants. It may prevent leaves from developing to their full size and cause them to fall early; the plants are weakened and checked in growth and shoots of badly infected plants may not harden off properly, so that they die back or are frosted.

The disease is easily prevented by spraying with 3 pints of colloidal sulphur in 100 gallons of water per acre/*4 kg in 1000 l per ha*, starting in late May and repeating the application two or three weeks later. If the disease is controlled by the first two sprays, no further spraying is necessary, but if the plants become infected again it may be necessary to continue regular spraying until the autumn.

It is most important with this disease to spray both sides of the leaf.

### 11.26 Needle Blight of Western cedar

*Didymascella* (*Keithia*) *thujina*. See Forestry Commission Leaflet No. 43 (1967 revision, or later).

This fungus attacks scale leaves of Western red cedar forming one or more characteristic brown or almost black spots or fruiting bodies on individual leaves. Heavily attacked plants are killed and others weakened substantially by the disease and there are many records of the loss of entire beds or sections of transplants in nurseries where the disease is established. These losses are most prevalent where plants have to remain in the beds or lines for two years rather than one.

*Keithia* can be controlled using a fungicide containing cycloheximide diluted in water to a concentration of 85 ppm and applied at the rate of 100 gallons of solution per acre/*1000 litres per hectare*. Two sprays, one in late March and one in late April, suffice in the drier easterly parts of the country. A third spray may be applied in mid June should symptoms then appear. This is most likely in the wetter parts of Britain.

The incidence of the disease may be reduced by strict nursery hygiene. All potential sources of infection within a wide radius must, if possible be destroyed; ideally, no Western red cedars should exist within a mile of a nursery. It is useless trying to raise nursery plants free from *Keithia* if one or more heavily infected tree is growing, whether as a specimen or a hedge, within a hundred yards of the nursery.

The risk of the disease building up can be further reduced if stocks can be moved every year and ground cultivated soon after; in this way, any fruiting bodies which have fallen to the ground over the winter are buried and cannot then discharge spores to infect nursery stock.

If there has been a severe attack of *Keithia* in a nursery, all Western red cedar stocks should be cleared out, and heavily infected stock burned. One growing season after, the species can be sown again or seedlings lined out. See also, Section 4.6—Rotation of Crops.

### 11.27 Other Diseases

Several other diseases have been occasionally recorded in nurseries. These include *Rhizina inflata* on the sites of bonfires, *Verticillium* spp., chiefly causing wilt of *Acer* species, *Phytophthora cinnamomi* on Douglas fir, *Ascochyta piniperda* causing die-back to shoots of *Pinus contorta*, and *Rosellinia quercina* on oak seedlings. *Thelephora terrestris* can also develop as a mat around seedlings and transplants and smother smaller individuals, though apart from the smothering and any physical damage when matted plants are separated, this fungus is not damaging.

No standard recommendations can be made for these diseases. Expert advice should be sought from:

The Pathologist
Forestry Commission Research Station
Alice Holt Lodge
Wrecclesham
Farnham, Surrey

or

The Pathologist
Forestry Commission Northern Research Station
Roslin
Midlothian
Scotland.

## 11.3 Insect Pests

Few insects regularly cause damage in the present-day nursery. However, numbers of any species may build up and cause appreciable loss in a particular year. Table 33 lists those which have, from time to time, caused such loss. In the table, moth larvae and beetles which, as larvae or adults, damage roots of nursery crops are listed first; springtails, a leaf miner and spinning mite follow and then moths and beetles which feed on foliage. Finally eight aphids and one similar sucking insect are listed. Details of the appearance of the insect at the stage it is damaging are given, followed by symptoms of damage, the months of the year when damage may be expected and the species damaged.

TABLE 33

INSECT PESTS FOUND IN FOREST NURSERIES

| Type of Pest | Latin Name | English Name and insect group | Damaging Stage | Description of Damaging Stage, and length of insect causing damage | Description of Damage, Habit of Feeding, etc. | Time of Damage | Tree Species attacked | Remarks |
|---|---|---|---|---|---|---|---|---|
| Root and stem feeder | *Agrotis segetum* | Cutworms—Turnip moth | Larva | Dirty grey-brown or grey-green lined larva; 40 mm | Feed at night; larvae eat seedlings through at 0—$\frac{1}{4}$ inch above ground level and may pull tops down into holes in ground. Small larvae may girdle seedlings | July—Sept.—May | All species | Watch for damage and holes in the ground from mid-July |
| | *Agrotis exclamationis* | Heart and dart moth | | Brownish larva with dark brown pear-shaped back marks. Yellowish stripe on sides; 50 mm. | | | | |
| | *Noctua (Triphaena) pronuba* | Large yellow underwing moth | | Dark brownish green larva with small head; eight dark bars on sides; 50mm. | | | | |
| ditto | *Hepialus humuli* | Ghost swift moth | Larva | Cream larva with oval orange-brown head. Body with horny brownish dots each with a short stiff hair; 50 mm. | Larvae eat out deep spiral groove or completely sever main root. | May—June | Young trans-plants of broad-leaves | Not uncommon near grassy sites |
| ditto | *Melolontha melolontha* | Cockchafer beetle | Larva | Characteristically curved larva with brown head and fat behind; 30 mm. 15 mm and 18 mm. respectively. | Larvae sever seedlings and young transplants below ground level. Young larvae prune roots. The species with longer life-cycle can cause damage through-out summer. Adults feed on leaves of hardwoods. | Any time during 3–4 year larval life | All species | Formerly a serious pest. Now seldom more than very local. Larvae damaged easily when soil is cultivated mechanically |
| ditto | *Serica brunnea* | | | | | 2 year larval life | | |
| ditto | *Phyllopertha horticola* | | | | | 1 year life July—Nov. | | |
| ditto | *Barypithes araneiformis* | Strawberry fruit weevil | Adult | Small black weevil; 2–3 mm. | Adults ring bark the stems of young seedlings and cause death. Very similar to young cut-worm damage, but earlier in season | May—June | All species | |
| | *Barypithes pellucidus* | Strawberry fruit weevil | | Similar to above but with long grey hairs; 2-3 mm. | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Root, stem and leaf feeder | *Strophosomus melanogrammus* | Nut leaf weevil | Adult | Weevil covered in brownish ashy scales, with black line between bases of wing cases; 4 mm. | Adults remove triangular chunks from needles, also patches of bark from young fine wood causing death of twigs. | April–May & Sept.—Oct. | All Species | Pests of new plantings as well as nurseries. Cause some damage in older trees. Most prevalent in nurseries adjoining older plantations. |
| ditto | *Otiorrhynchus singularis (picipes)* | Clay-coloured weevil | Adult & Larvae | Clay-coloured weevil; 5.5–7 mm. | Larvae feed on roots and can sever the root system of young seedlings about an inch below the soil surface. | April–Oct. | | |
| ditto | *Otiorrhynchus ovatus* | Strawberry root weevil | Adult & Larva | Black weevil; 5 mm. | Adults damage plants in similar way to *O. singularis* Larvae carry out heavy root-pruning. | May–June peak | All species | |
| Leaf and stem feeder | *Bourletiella hortensis* | Springtails *Collembola* | Adult & Nymph | Minute grey jumping wingless insect resembling flea | All stages feed upon germinating seed at the shoot apex causing thickening and distortion of leaves, and bushy-topped seedlings, which in subsequent years produce multiple-leadered culls. | May–Aug. | Seedlings of all conifer species | Occasionally confused with Turnip flea beetle (*Phyllotreta* spp.) |
| Leaf miner | *Eucosma tedella* | Spruce needle miner (moth) | Larva | Greenish or yellow/brown larva with red brown lines down back. Brown head and neckshield; 9 mm. long. | Mined needles turn brown, these are spun to shoot in a "nest" which contains much silk, frass and needle remains. | Aug–Oct. | Spruces | |

(*continued*)

TABLE 33 (cont.)

| Type of Pest | Latin Name | English Name and insect group | Damaging Stage | Description of Damaging Stage, and length of insect causing damage | Description of Damage, Habit of Feeding, etc. | Time of Damage | Tree Species attacked | Remarks |
|---|---|---|---|---|---|---|---|---|
| Leaf feeder (sucker) | *Paratetranychus ununguis* | Conifer spinning mite | Adult & Juvenile | Microscopic semi-transparent red and green mite. | All stages feed usually on underside of needles causing wilt and fall. Needles turn dingy yellow and threads of silk are plentiful. | May–Sept. | Spruces | Will also attack other conifers. |
| Leaf feeder (biter) | *Carura vinula* | Puss moth | Larva | Large green larva with white-edged saddle-shaped purple band down length; 50 mm. | Larvae eat out chunks of leaf. | July/Aug. | Poplar and other hard-woods | |
| ditto | *Leucoma salicis* | White satin moth | Larva | Dark grey larva with large pale yellow or white dots down back and 3 pairs of bright red hairy warts on each segment; 40 mm. | | April–June | ditto | |
| ditto | *Operophtera brumata* | Winter moth | Larva | Green with dark stripe down back, 2 white lines outside this, and beneath these a pale yellowish line. Head green sometimes marked black; 25 mm. | Small larvae eat out chunks from the bud or mine inside it. Older ones spin leaves together and feed on neighbouring foliage, eating out chunks from the leaves. | April–May | ditto | Will also attack conifers. |
| ditto | *Operophtera fagata* | Northern winter moth | Larva | Green with grey stripe down back, 2 similar coloured stripes on each side, edged above with yellowish white. Head black; 25 mm. | | May–June | ditto | |
| ditto | *Erannis defoliaria* | Mottled umber moth | Larva | Colour variable. Reddish brown above and yellowish on sides and below. There is also a black side-line edged with interrupted white. Head brown; 25 mm. | | May–June | ditto | |

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|---|---|---|---|---|---|---|---|---|
| ditto<br><br>ditto | *Phyllodecta vitellinae*<br><br>*Phyllodecta vulgatissima* | Small poplar leaf beetles | Larva & Adult | Dirty grey-brown larvae with black dots; 5 mm.<br><br>Adults metallic blue or green; 5 mm. | Leaf skeletonized on under sides.<br><br>Larvae feed closely side by side.<br>Adults may gnaw young shoots. | May–Sept. | Poplars | Two generations a year. |
| ditto | *Chalcoides aurata* | Willow flea beetle | Adult | Wing cases green or violet, head copper; 2 mm. | Produce small holes in leaf. | May–Aug. | Poplars | |
| ditto | *Trichiocarpus viminalim* | Poplar sawfly | Larva | Larvae as they develop from pale green, through light yellow and finally to orange with black dots; 20 mm. | They feed side by side and skeletonize under side of leaf. | July–Sept. | Poplars and Willows | Two generations a year. |
| ditto | *Croesus septentrionalis* | Hazel sawfly | Larva | Larva develop from pale green with black dots, through green with black and yellow dots, to greenish yellow with prominent black patches; 25 mm. | Eat out chunks of leaf. | June–Sept. | Hard-woods | Possibly two generations a year |
| ditto | *Nematus salicis* | Large willow sawfly | Larva | Larva blue green except for first and last 3 segments which are red brown. The whole dotted with black; head black; length 25 mm. | Eat out chunks of leaf. | May–Oct. | Hard-woods | Two generations a year. |
| Shoot and leaf suckers | *Cinara pilicornis* | Brown spruce aphis | Adult & Nymph | Light brown to grey-brown aphis. | Slight twist to current years shoots on which it feeds in colonies. Needles sometimes become brown as if frosted. | May–July | Spruces | Produces copious quantities of honeydew on which sooty moulds grow. |

(*continued*)

TABLE 33 (cont.)

| Type of Pest | Latin Name | English Name and insect group | Damaging Stage | Description of Damaging Stage, and length of insect causing damage | Description of Damage, Habit of Feeding, etc. | Time of Damage | Tree Species attacked | Remarks |
|---|---|---|---|---|---|---|---|---|
| Shoot and leaf suckers | *Elatobium abietinum* | Spruce aphis | Adult & Nymph | Wingless globular bright green aphis. 1 mm. | Feeds in colonies on underside of needles. Causes yellowing and loss of needles. | July–May | Spruces | More serious in standover crops. |
| ditto | *Schizolachnus pineti* | Pine needle aphis | Adult & Nymph | Grey aphis with some wax. May form long dense colonies. 2 mm. | Feeds on needles causing some browning. | June–Aug. | Pine | |
| ditto | *Prociphilus pini* | Pine root aphis | Adult & Nymph | Small white aphis. Bluish waxy wool with globules of honey-dew. 1–2 mm. | Feeds on roots, can cause browning and wilt of whole plant. | Through out Spring and Summer | Pine | |
| ditto | *Aphis fabae* | Black bean aphis | Adult & Nymph | Dark grey aphis. 2 mm. | May cause loss of needles or death of seedlings. Feeds near shoot apices. | Aug.–Oct. | Spruce Larch Pine Hem-lock | First observed in 1962 |
| ditto | *Phyllaphis fagi* | Beech aphis | Adult & Nymph | Yellow to green aphis on under side of beech leaves. Plentiful wax wool. 2 mm. | Aphids feed on underside of leaves causing them to wilt, turn brown and fall. Plentiful honeydew. | May–July | Beech | A heavy infesta-tion can seriously check growth. |
| ditto | *Myzus cerasi* | Cherry black fly. | Adult & Nymph | Blackish aphis forming dense colonies under leaves. Much honeydew. 2 mm. | Aphid sucks new leaves which curl. Shoots may die back. | May–July | Cherry | |

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|---|---|---|---|---|---|---|---|---|
| Shoot and leaf suckers | *Pineus pini* | Pine woolly adelgid | Adult & Nymph | Minute black adelgid covered in waxy wool | Feeds on bark of branches and young stems. Can cause some browning of foliage. | May & through out summer | Pine | |
| ditto | *Adelges cooleyi* | Douglas fir adelgid | Adult & Nymph | Black adelgid with waxy wool. 1 mm. | Adelgids feeding on underside of needles cause distortion and sometimes needle yellowing and loss. | June–July peak | Douglas fir | Mainly a forest pest but can occur in the nursery on 2nd year and older plants. |
| ditto | *Typhlocyba cruenta* | Beech leaf-hopper | Nymph & Adult | Yellow/brown, elongate. 3–4 mm. | Animal jumps like a flea. Sucks sap from leaves like an aphid causing them to go chestnut brown. | May–July | Beech | |

### 11.31 Control of Insects

The first essential for successful control of insect and other pest is a sharp eye. Most insects become active in early May. During May and June and for the rest of the summer a continued watch should be kept for pests, in particular on the undersides of leaves and needles. When seen, appropriate measures can be taken to knock out infestations before they cause more than local damage.

For all practical purposes, the only effective methods of control require the use of insecticides. Nursery practice can however influence the frequency with which certain control measures have to be put into effect. To keep insects down, possible sites where numbers can build up must be eliminated as far as possible. Beech should therefore not be used as a hedge within nurseries or as a surround, if beech seedlings or transplants are to be raised. Weevils and some other species listed in table 33 are likely to be more prevalent if coniferous plantations immediately surround the nursery.

Soil insects are generally much more troublesome in nurseries where crops stand for two years than in those where seedlings or transplants are usually lifted after one year.

### 11.32 Selection of Insecticide

TABLE 34

INSECTICIDES RECOMMENDED AGAINST NURSERY PESTS

| Type of Pest | First-choice Material | Alternative Material |
|---|---|---|
| Moth and Sawfly larvae | gamma BHC | DDT |
| Beetles and weevils | gamma BHC | DDT |
| Aphids | 'Malathion' or gamma BHC | |
| Springtails | 'Malathion' | |
| Cutworm | gamma BHC | |
| Cockchafer | gamma BHC dust | |
| Mites | 'Dicofol' ('Kelthane') | |

Liquid formulations are recommended rather than dusts, because they are usually made up with a "sticker" so that once applied and allowed to dry on the plant they will not easily be washed off by rain, they are transportable as concentrates and the machinery for their application is simpler and cheaper, more efficient and easier to maintain than that for dusts.

### 11.33 Names of Available Products

Proprietary brands of the insecticides listed in Table 34 will be found in the current *List of Approved Products* issued under the Agricultural Chemicals Approval Scheme. The products listed there have been approved for their biological effectiveness and for safety under the Pesticides Safety Precautions Scheme. The current *List of Approved Products* can be obtained from any Ministry of Agriculture, Fisheries and Food Divisional Office or from the Ministry of Agriculture, Fisheries and Food (Publications), Tolcarne Drive, Pinner, Middlesex.

### 11.34 Rate of Application

When using any material recommended in Table 34, foliage and stems should be sprayed so that all surfaces are wetted, but without run-off of the spray solution. On seedbeds and transplant lines, sprays are best applied uniformly over all plants, rather than attempting to spray heavily infested plants individually. In most instances, 60 gallons per acre/*600 litres per hectare* of spray will suffice but for dense crops and pests in the soil, this should be increased to 100 gallons per acre/*1000 litres per hectare.*

The concentration of the spray depends on the material used. See below.

## 11.4 Notes on Insecticides

### 11.41 gamma BHC Emulsion or 'Lindane'

This is sold as a 20 per cent emulsion of the gamma isomer of benzene hexachloride. It is a powerful insecticide, related to DDT. It has excellent contact and stomach effects, fair residual properties, and good fumigant action for the first day or so after application. It is probably the best general purpose insecticide and should be used at the rate of 1 pint of 20 per cent emulsion per 100 gallons of water/*0.125 litre of emulsion per 100 litres of water.* (BHC "technical", i.e. crude benzene hexachloride containing all the isomers, is an evil-smelling product with phytotoxic properties and should be avoided).

*gamma BHC Dust*

This material, which is sold as 0.5 per cent formulation, is a proven alternative to aldrin (now banned) for cockchafer control. It should be applied at 1 to 1½ cwts per acre/*125 to 190 kg per hectare* and may be either worked into the top 4 inches/*10 cm* or so of soil between transplant rows in June or, worked in during the last cultivation before planting or sowing takes place.

### 11.42 DDT

DDT is a highly persistent material and for this reason should only be used as a last resort.

It is normally sold as a 25 per cent emulsion and is a powerful contact and stomach insecticide with great residual properties and chemical stability, but has little fumigant effect. It should be sprayed at a concentration of 3 to 4 pints of 25 per cent emulsion per 100 gallons of water/*0.375 to 0.5 litre of emulsion per 100 litre of water*, 3 pints per 100 gallons/0.375 *litre per 100 litres* is suitable for soft bodied larvae and 4 pints per 100 gallons/*0.5 litre* per 100 litres for tougher-skinned beetles and weevils.

### 11.43 Malathion

This is sold as a 60 per cent emulsion. It is a powerful aphicide and general insecticide with a very strong fumigant effect. It is not a particularly stable compound and should not be stored for more than a year. It is the most effective insecticide against *Collembola*. Spray at 1½ pints of emulsion per 100 gallons of water/*0.2 litre per 100 litres* to control aphids and *Collembola*. For the latter use 100 gallons of spray solution per acre.

### 11.44 'Dicofol' ['Kelthane']

This is sold as a 20 per cent emulsion. 'Dicofol' is a slow acting acaricide effective against spinning mite. The full results of its application may not show themselves for 5 to 7 days.

## 11.5 Protection of Seedbeds Against Birds

Birds have been known to eat all the seed sown on seedbeds. The loss of practically 100 lb of pine seed due to feeding by small birds has been recorded. Such severe damage is exceptional but in most nurseries there is some feeding mostly by greenfinches, chaffinches and sparrows. Linnets, skylarks, crossbills and pigeons can also do severe damage. Birds do most harm to sowings of species with large seeds such as Corsican pine, *Pinus strobus* and *P. peuce* and some hardwoods. Species like Western hemlock are seldom troubled.

Capercailzie have extensively damaged pine in Scottish nurseries by feeding on young growing shoots.

Pheasants may feed on oak, beech or Sweet chestnut seed if sown in the autumn.

The only certain counter-measure to birds feeding on seed is a complete physical barrier of netting over the seedbeds. Bird scarers of flashing metal, strings of cartridges or carbide bangers may be effective for a few days but the birds get used to them and subsequently ignore them. 'Thiram' seed dressing can reduce but not entirely eliminate damage.

### 11.51 Netting against Birds

A suitable physical barrier may be made using 3/4 inch mesh/*2.0 cm* polythene netting laid across seedbeds immediately after sowing and supported on flattened hoops of No. 8 or No. 10 galvanised wire (Plate 31). The hoops should not project more than 6 inches/*15 cm* above the seedbed at the highest point, so that a tractor can be used to apply a pre-emergence spray through the netting. Short lengths of wire bent over at one end should be used to pin down the edges of the netting in contact with the soil so that birds do not get under it. The netting must also not be allowed to droop in the middle; otherwise birds will peck through it (Plate 31). Properly erected, such a barrier should keep birds away completely. The netting must be put over beds as soon as possible after sowing and may have to remain for six to nine weeks after sowing. It may be taken away once the seedlings have started to produce the first true leaves.

Although polythene netting is relatively easy to put over beds, it is quite expensive, both in capital outlay and in the labour of handling it. Polythene netting is nevertheless both easier to handle and cheaper to buy than galvanised netting. Also, the zinc used in galvanised netting can render the soil toxic to nursery plants; this risk is serious wherever netting remains in position for several months, especially where air is heavily polluted. On ground where galvanised netting is left rolled up for any length of time, plants may subsequently fail to grow. (See also Section 4.46).

### 11.52 Seed-dressings to Deter Birds

The use of a seed-dressing rather than netting is recommended where losses are believed to be less than 25 per cent annually. If in doubt, net a few square yards of representative sowings, and count the emerged seedlings inside and outside the netting in mid-June.

The material recommended is thiram, formulated as a seed-dressing such as in 'Fernasan S'.

*'Fernasan S' is an irritant and can affect the eyes, membranes of the nose and the skin. A face-mask, goggles and rubber gloves must be worn throughout the dressing procedure. Rubber gloves should be worn when handling the treated seed for sowing.*

Where more than 5 lb/*2 kg* of seed is to be dressed, a drum should be big enough to hold at least twice the volume of seed. The drum should have a lid. If less than 5 lb/*2 kg* of seed is to be dressed, a stout polythene bag should be used. A supply is also required of 'Bedacryl 227' latex (Suppliers ICI Dyestuffs Division, Blackley, Manchester). For pine seed, 5 ml of latex are needed per lb of seed while for spruce seed, 8 ml are needed per lb/*11 and 18 ml per kg* respectively. For other species use one or other of these rates, the larger seeded species requiring less than small seeded species.

*The procedure for preparation is:*

Weigh seed to be treated; calculate what is 15 per cent of the seed weight; weigh out this amount of 'Fernasan S'.

Knowing the seed weight and species, measure out the volume of latex required, and dilute this immediately by mixing it with water equal in volume to nine times the volume of the latex.

Place seed in a drum or plastic bag; the container should not be more than half filled with seed. Pour in the diluted latex, close the container and revolve or shake until all the seed is coated with latex.

Immediately tip in about one-third of the 'Fernasan S'; close the container and revolve or shake until all the powder is taken up; repeat twice using up remaining seed dressing.

Pour out seed onto a polythene sheet, spread to a thickness not more than half an inch in depth and leave to dry for 12 hours.

Seed is then ready for sowing, or it may be stored in bags for two or three weeks if sowing is delayed.

### 11.6 Protection of Seedbeds against Mice

If mice are thought to be damaging seed, traps should be set. If the damage is too severe to be controlled by trapping or if the seed is particularly valuable, a temporary mouse-proof fence may be erected round the seedbeds concerned. The fence should be of ¼ inch mesh galvanised netting. It need be no more than 24 inches/*60 cm* wide, with four inches/*10 cm* buried in the ground and the top three inches/*8 cm* curled over away from the seedbeds to prevent mice from climbing over. Joins in the netting must be made mouse-proof. Traps should be set within the fence to catch any mice already inside it.

### 11.7 Damage by other Animals

If freedom from rabbit damage is to be guaranteed, a rabbit fence is virtually essential. See Forest Record 80, esp. Fig 34 (Pepper and Tee, 1972).

Hares and deer occasionally get into nurseries. Hares are rarely more than a nuisance, but if deer, present in the locality, are regular visitors, a deer fence should be put up around the nursery. The cheapest form of deer fence is a 3 ft/*1 m* width of broad mesh netting erected above a standard rabbit fence, to give a total height of 6 ft *2 m*.

Dogs, foxes and badgers occasionally get into a nursery and dig holes but the damage they do is insignificant.

Moles are seldom troublesome in a nursery but where they do occur they should be trapped. A licence is required before strychnine can be used to poison moles.

### Further Reading

Goodey, J. B., 1965. The relationship between the nematode *Hoplolaimus uniformis* and Sitka spruce. (Supplementary paper in) Bulletin 37, Forestry Commission, London, 210–211. Vol. I.

Griffin, D. M., 1965. A study of damping-off, root damage and related phenomena in coniferous seedlings in British forest nurseries. (Supplementary paper in) Bulletin 37, Forestry Commission, *Nutrition Problems in Forest Nurseries*, London, 212–227. Vol. I.

Martin, H., editor, 1969. *Insecticide and Fungicide Handbook*. 3rd edn., Oxford: Blackwells Scientific Publications.

Pawsey, R. G., 1964. *Needle cast of pine*. Leaflet No. 48, Forestry Commission, London.

Pawsey, R. G., 1964. *Grey mould in forest nurseries*. Leaflet No. 50, Forestry Commission, London.

Peace, T. R., 1962. *Pathology of trees and shrubs with special reference to Great Britain*. Oxford: Clarendon Press.

—1948. *Chafer beetles*. Leaflet No. 17, Forestry Commission, London.

Pepper, H. W. and Tee, L. A., 1972. *Forest Fencing*. Record No. 80, Forestry Commission, London. (H.M.S.O. 35p).

Phillips, D. H., 1963. *Leafcast of larch*. Leaflet No. 21, Forestry Commission, London.

—1956. *Oak mildew*. Leaflet No. 38, Forestry Commission, London

—1967. *Keithia disease of Western red cedar, Thuja plicata*. Leaflet No. 43, Forestry Commission, London.

Rowe, Judith J., 1971. Prevention of damage by birds and mammals in forest nurseries. *Quarterly Journal of Forestry*. 65 (2), 148-157.

Salt, G. A., 1967. Effect of Seedborne Fungi on the Viability of Sitka spruce Seed. *Report on Forest Research*, 1966, 104–106.

# Chapter 12

# VEGETATIVE PROPAGATION

Few of the species commonly planted in the forest for timber production can readily be propagated vegetatively. Among the conifers, only Lawson cypress, Western red cedar and Leyland cypress root freely from cuttings, and among the hardwoods only poplars, willows, London plane and elms. Nevertheless, vegetative propagation is the only means of increase of some forms or varieties of these species, such as disease-resistant clones of poplar and elm, selected varieties of willow, and the hybrids: Leyland cypress and London plane. *Metasequoia glyptostroboides*, the seed of which is extremely difficult to obtain at present, is also readily propagated from cuttings.

For species such as Lawson cypress and Western red cedar which can be rooted easily but which can also be raised from seed, the cost of production of one-year old rooted cuttings is at least three times that of corresponding plants raised from seed, and in practice only ornamental varieties are rooted on any scale.

The White, Hybrid black and Balsam poplars, London plane and the willows are all readily propagated from hardwood cuttings in the open ground, but the Grey poplar and aspen, Leyland cypress and selected clones of elm require units equipped with soil-heating and mist-watering if a high proportion of cuttings are to be rooted.

Once a stock of a particular variety has been established in the nursery, there should be no need to bring in further stock plants unless the whole stock 'is lost in some calamity. However, after a number of years, stools lose their original vigour and need to be replaced.

## PROPAGATION IN OPEN GROUND

### 12.1 Poplars and Willows. Plates 26 to 28

The recommended timber-producing poplars are the Grey poplar, *Populus canescens* the following Hybrid black poplars: *Populus* 'Casale 78' (for southern England only), *P.* 'Eugenei', *P.* 'Gelrica', *P.* 'Heidemij' formerly called *P. deltoides missouriensis*), *P.* 'Laevigata', *P.* 'Marilandica', *P.* 'Robusta' and *P.* 'Serotina' the Balsam hybrid *P. tacamahaca* x *trichocarpa* 32 and *P. trichocarpa* 'Fritzi Pauley'. (See also Forestry Commission Bulletin 19 *Poplars*, FC Leaflet 27, *Poplar Cultivation*, and Leaflet 39, *The Quality of Poplar Plants*). The willow planted for cricket bat timber is *Salix alba* var. *caoerulea;* the only others planted commercially (other than for sale as ornamentals) are those for basket-making which include *Salix triandra*, *S. viminalis*, and *S. purpurea*. (See Forestry Commission Bulletin 17, 3rd edition, *Cultivation of the Cricket Bat Willow*).

The poplars and willows of the recommended timber-producing clones are easily raised from hardwood cuttings from dormant shoots; about 90 per cent of such cuttings should normally grow to become usable plants. Three other species of poplar are sometimes required for ornamental planting—the White poplar, the Grey poplar and the aspen. The White poplar, *P. alba* can be raised from hardwood cuttings though these root less easily than cuttings of the hybrid balsams or the Black poplars. The Grey poplar, *P. canescens*, is often difficult to root from hardwood cuttings and a steady supply of plants of this species together with the difficult forms of the White poplar is best obtained by taking softwood cuttings in the summer and rooting them in a heated frame (see Section 12.7). The Grey poplar also forms suckers and when only a small number of plants is required, young rooted sucker shoots may be detached from the parent tree and transplanted in the nursery for a year or two. The method is not always satisfactory however, and cannot be recommended for large-scale production. The European aspen, *P. tremula*, is almost impossible to propagate from hardwood cuttings; it is best to raise plants from seed unless selected clones are required, when again a heated frame is required. (See Forest Record No. 2, *The Raising of Aspen from Seed*).

### 12.11 Supply of Desirable Poplar Varieties

In the nursery, many of the hybrid black poplar varieties are virtually indistinguishable, yet they differ considerably in form, rate of growth and in resistance to the most serious disease of poplar in Britain, bacterial canker. The intending grower must, therefore, buy cuttings and plants of good varieties, raised from stock of known origin. The Balsam poplars are more easily separated botanically, but because so many are also susceptible to canker, the same care is needed in obtaining stocks. During every stage of propagation, different varieties *must* be carefully labelled and should be separated in the nursery by a marker or row of plants of a different genus. Lawson cypress is useful in this role.

### 12.12 The Site for a Poplar Nursery

The site should be fertile and sheltered. The best growth of poplars is obtained in nurseries where the pH is between 5.5 and 7.0. The soil should work easily and remain reasonably moist during the growing season. Clay soils and dry sands are normally to be avoided. All poplars are heavy feeders and soil fertility must be maintained by regular addition both of organic matter such as hop-waste and of inorganic fertilisers. Hop-waste should be applied at least every second year, at 20 tons to the acre/*50 tonnes per hectare*. In addition a balanced potassic superphosphate fertiliser (analysis for example 0; 20% $K_2O$; 20% $P_2O_5$) should be applied each year at 5 to 7 cwt per acre/*750 kg per hectare* and should be worked into the soil shortly before planting. 'Nitro-chalk' or a similar nitrogen fertiliser should be spread in early June at about half this rate.

### 12.13 Poplar Cutting Material. Plates 26 and 27

It is essential to use only good quality cuttings if vigorous growth is to be obtained in the first year. Cuttings should be 8 to 9 inches/*20 to 23 cm* in length, taken from straight, well-ripened one-year old shoots with strong well-formed dormant buds. Cuttings less than ⅜ inch/*1 cm* in diameter should be discarded, together with soft or succulent shoots, thick cuttings with small buds or side shoots (i.e. 'blind' cuttings) and cuttings which are crooked and therefore difficult to insert into the ground. The top end of the cutting should be cut just above a bud. Blind or weak cuttings will often strike but the plants produced from them will be small. Material can be prepared at any time between leaf-fall and the end of March, cutting the shoots with sharp secateurs or knife. Plates 26 and 27 illustrate good and bad cuttings.

### 12.14 Growth of One-Year-Old Poplars from Cuttings

In early spring, the ground should be well-cultivated to a depth of at least 8 inches/20 *cm* and the cuttings pushed vertically into the soil shortly afterwards until the upper end is level with the soil surface. The cuttings should be spaced 15 inches between cuttings and 18 inches between rows/*40 by 50 cm* at least. If the soil has been properly cultivated beforehand, it will settle slightly, leaving the tops of the cuttings slightly exposed. When buds break, two or more shoots may be thrown up by each cutting. After the risk of late spring frost has passed, and the shoots are 6 to 8 inches/*15 to 20 cm* tall, the strongest and straightest of these should be selected as the leading shoot and others removed. Thereafter, the ground should be hoed or sprayed carefully to control weed growth. Weeds should never be allowed to form a mat under the poplars. Occasionally, plants will have to be sprayed to control attacks by weevil or beetles. See Section 11.3 for details.

At the end of the season, one-year rooted cuttings (C1+0) should be from 5 to 7 feet/*1.4 to 2 m* tall: those which are 6 feet/*1.7 m* or more in height and which are sturdy and well branched are suitable for planting out (Plate 28).

### 12.15 Growth of Two-Year-Old Poplars

Those one-year-old plants which are too small for planting should be lifted and replanted at 2 feet to 3 feet/*0.6 to 0.9 m* spacing in ground prepared in the same way as for cuttings. Stock less than 3 feet/*0.9 m* tall should be discarded. After planting, the main stem should be cut back to within 1 inch/*2 cm* of the top of the original cutting. The shoots so removed can be used for cuttings and this is an important way of increasing stocks. The stumped back transplants will often make as much growth in one year as would have been made by uncut plants in two years; stumped plants are also usually sturdier and better branched.

In the early part of the season, the shoots from a stumped plant should be singled, favouring the strongest and straightest shoot, in the same way as for cuttings. Later, a few strong side branches on the lower stem may be removed if necessary to allow access between the rows of plants; any forked growth should also be corrected at this time to encourage proper development of the leading shoot. After one year in the transplant lines, the plants, having a two-year-old root system and a one-year-old shoot (C1+S1) will almost always be suitable for planting out and will often be over 8 feet/*2.3 m* tall. They are as easily established as well-grown one-year-old plants. However, they are bulky to transport, more time-consuming to plant and may require staking.

Plants may also be grown from cuttings for two years without disturbance. Such plants are likely to be taller than stumped transplants and may require more careful handling and deeper planting if good results are to be obtained.

### 12.16 Lifting One and Two-Year-Old Poplars

At lifting, the longer roots may be shortened to facilitate packing and subsequent transport; such roots must be cut and not torn. The lower branches may be shortened to about 9 inches/*20 cm* at the time of lifting if this is likely to facilitate subsequent handling and transport.

### 12.17 The Poplar Stool Bed

By cutting back one-year-old rooted cuttings each year, many growers will have sufficient cutting material to meet their needs. For large-scale propagation, however, a regular supply of cuttings is most conveniently obtained from stool beds. The young stools should be spaced at 4 by 4 feet/*1.2 by 1.2 m* and cut back after planting and at the end of each successive season. The shoots produced in successive years from stools will increase in number and quality until, by the fourth season, each stool will be producing between twenty and sixty cuttings. Like the cutting and transplant beds, the stoolbed should be on good ground. With regular manuring, stools should remain vigorous until they are six or seven years old at least.

### 12.18 The Production of Poplar Sets

Long cuttings or sets can be established satisfactorily on the most favoured planting sites, but as sets are planted without roots, their survival rate is usually lower than that of rooted plants and their growth is appreciably slower for several years after planting. They should only be used on moist, fertile sites, when surrounding weed growth can be suppressed to aid establishment. One-year sets are usually too small for this use and stools reserved for the production of sets should be left uncut for two years. A two-year-old set from a vigorous stool will be at least 8 feet/*2.3 m* tall. It may have a pronounced basal bend which should be removed at planting.

### 12.19 Willows

Traditionally, willows have been planted as sets. However, rooted plants are being used increasingly, to ensure good growth and straight stems. Rooted plants can be raised both from cuttings and sets. Plants are raised from 9 in/*22 cm* cuttings, ½–1 in/*13–25 mm* thick, in the same way as poplar cuttings. Sets are grown on stools 3 ft/*90 cm* apart. Shoots 8–10 ft/*2.5–3m* should be cut and planted in the nursery at 1–2 ft x 2–3 ft/*30–60 cm x 60–90 cm*, remaining for one or two years according to size and growth.

## 12.2 London Plane. Plate 29

This well-known tree of the streets, parks and squares of London is thought to be a hybrid between *Platanus orientalis* and *P. occidentalis* and was first identified at the Oxford Botanic Gardens in about 1670. Now named P. × *acerifolia*.

The hybrid is best propagated from cuttings; reproduction by layering is possible but is laborious and is only recommended where a relatively small number of plants is required.

Seeds are best collected in late winter and sown dry in March; but they give an erratic yield of seedlings.

### 12.21 Plane Cutting Material

Cuttings must be taken off well ripened current shoots. Usually only one cutting can be obtained per shoot, and this is taken from the base, the remaining growth being too thin.

Cuttings should be 7 to 9 inches/*20 cm* long, $\frac{3}{16}$ to ¼ inch/*0.5 to 0.8 cm* in diameter and with at least four buds. Very vigorous, rapidly grown shoots with 4 inches/*10 cm* or more between buds do not root as well as sturdy shoots with buds every 2 to 3 inches/*5 to 8 cm*. Cuttings should be cut cleanly with a sharp knife, leaving a well-formed bud just above the base and another just below the top. It is important to take cuttings at the time of leaf fall, which is usually during late October or early November.

The ability of cuttings to root is affected by the age of the parent tree; for best results cuttings should be taken from young trees up to twenty years old.

Where propagation has to be sustained over several years, it is advisable to plant stock trees to supply cuttings, pollarding them each year to get the maximum number of shoots. From 20 standards with crowns 4 to 6 feet/*1 to 1.7 m* across when in growth, 1500 cuttings have been obtained annually.

### 12.22 Inserting Plane Cuttings

Cuttings should be inserted while the soil is sufficiently warm to promote callousing before winter, i.e. October or early November. Cuttings put in later may rot.

A V-shaped trench with one vertical side should be dug and cuttings placed upright, the tops being less than 1 inch above the soil surface. A small amount of soil should be placed over the bottom of the cutting and should be well firmed down. The trench should then be filled up and the soil firmed down again and lastly the soil should be levelled. The ground should be firmed down finally about a month later or at the first subsequent time when the soil is reasonably dry. In early spring, any cuttings which have been raised in the soil by frost should be pushed in again.

Cuttings should be spaced at 4 inches in the row and 10 inches between rows/*10 by 25 cm*. Rooting takes place principally at the base and also from just below the buds. There is little inter-nodal rooting.

### 12.23 Protection of Plane Cuttings

Shading with lath shelters about 1½ feet/*0.5 m* above the soil to reduce transpiration is advisable. Shelters should remain over the cuttings from just before flushing commences in the spring until the first growth has hardened off (around mid to end of July).

### 12.24 Yield from Plane Cuttings

With satisfactory cutting material and shading, up to 70 per cent of the cuttings should root. If such yields are not obtained, it may be beneficial to dust the base of the cuttings in indolyl butyric acid in talc.

The most vigorous one-year rooted cuttings are suitable for planting, but the smaller plants require to be lined out for a further year.

## PROPAGATION UNDER COVER

Cultivars difficult to raise in the open nursery can often be raised under cover. If large numbers of plants are required, more closely controlled conditions and higher rates of work can be obtained in a greenhouse with controlled temperature and automatic watering. If only a few plants are required, a small frame with soil heating such as that illustrated in Fig. 5 will undoubtedly serve the purpose well. However, new systems, in particular those involving plastic houses, are being developed rapidly and it is likely that within the next decade, the traditional frame will be obsolete.

### 12.3 The Frame or Greenhouse

The propagating unit must provide an environment where a high humidity and a regulated soil temperature can be maintained while rooting is in progress. For efficient propagation of the more difficult species, mist watering and soil heating are essential.

Once cuttings have rooted, they have to be "hardened off", i.e. acclimatised to the dryness of normal conditions out of doors. Plants are best hardened off where they were rooted; however, if mist and heating are available only in part of the unit, newly rooted stock should be bedded out and the unit refilled with fresh cuttings.

For every one hundred rooted cuttings to be produced at any one time, 3 sq feet–*0.3 sq m* of bench or frame space should be allowed. Any separate hardening off unit should be one third of the area of the main unit.

### 12.31 Services and Materials

A ¾ inch rising main should supply water at 50 to 60 lb psi/*3.5 to 4.3 kg per sq cm.* If a supply is only available at a lower pressure, a booster pump is required. If possible, the water should be soft; hard water forms chalky deposits on the foliage when cuttings are in the rooting medium for some time and evaporation rates are high. This can be combatted by increased shading.

All beds and benches that have mist-watering facilities must be horizontal, otherwise water from higher pipes will drain out of those below.

The electrical power supply must provide between 5 and 6 amps for each 100 sq feet/*9 sq m* surface area of the rooting medium, in addition to the current needed for fans, space heaters, pumps ect.

Drainage below the rooting medium should be through broken brick or hardcore. Clinker corrodes the heating wires.

Any timber used to frame the rooting medium should be treated with a copper-based preservative. Creosote should not be used.

### 12.32 Rooting Medium

The rooting medium should be made up of:

| | |
|---|---|
| 25 per cent | Coarse sand |
| 25 per cent | Sharp grit or gravel passing a ⅛ to $\frac{3}{16}$ inch/*3 to 4 mm* mesh screen |
| 50 per cent | Granulated horticultural sphagnum peat |

A better-drained rooting medium is required in a mist-frame than in a hand-watered frame.

Sedge peat does not provide a suitable rooting medium; it is too alkaline and should be avoided.

In mist-frames, the rooting medium should be changed every one or two years.

### 12.4 Leyland Cypress. Plate 30

This hybrid between *Cupressus macrocarpa* and *Chamaecyparis nootkatensis*, called × *Cupressocyparis leylandii*, was first observed in 1880 at Leighton Hall, near Welshpool, though not identified and described until 1925. Several different individual hybrids are known and two at least have been quite widely propagated from cuttings. The timber is of good quality and the ability of the tree to grow rapidly on a wide range of sites justifies the present interest in it. In the garden, it forms a shapely specimen or makes a dense rapidly growing screen or hedge.

The hybrids do not bear fertile seed, and until it can be re-created on a large scale by controlled cross-pollination of the parent species, Leyland cypress has to be propagated vegetatively. It can be raised in a cold frame when rooting takes up to 12 months. However, for the most economic sustained plant production, cuttings should be rooted in heated beds. The percentage of cuttings that can be made to root within a reasonable period of time depends to some extent on the clones; under good conditions and with a free-rooting clone, between 50 and 70 per cent of the cuttings should be well-rooted when the frame is due to be cleared. Where a frame with heat and mist-watering equipment is being used mainly for the production of Leyland cypress, two batches can be rooted per year, one lot being inserted in March and

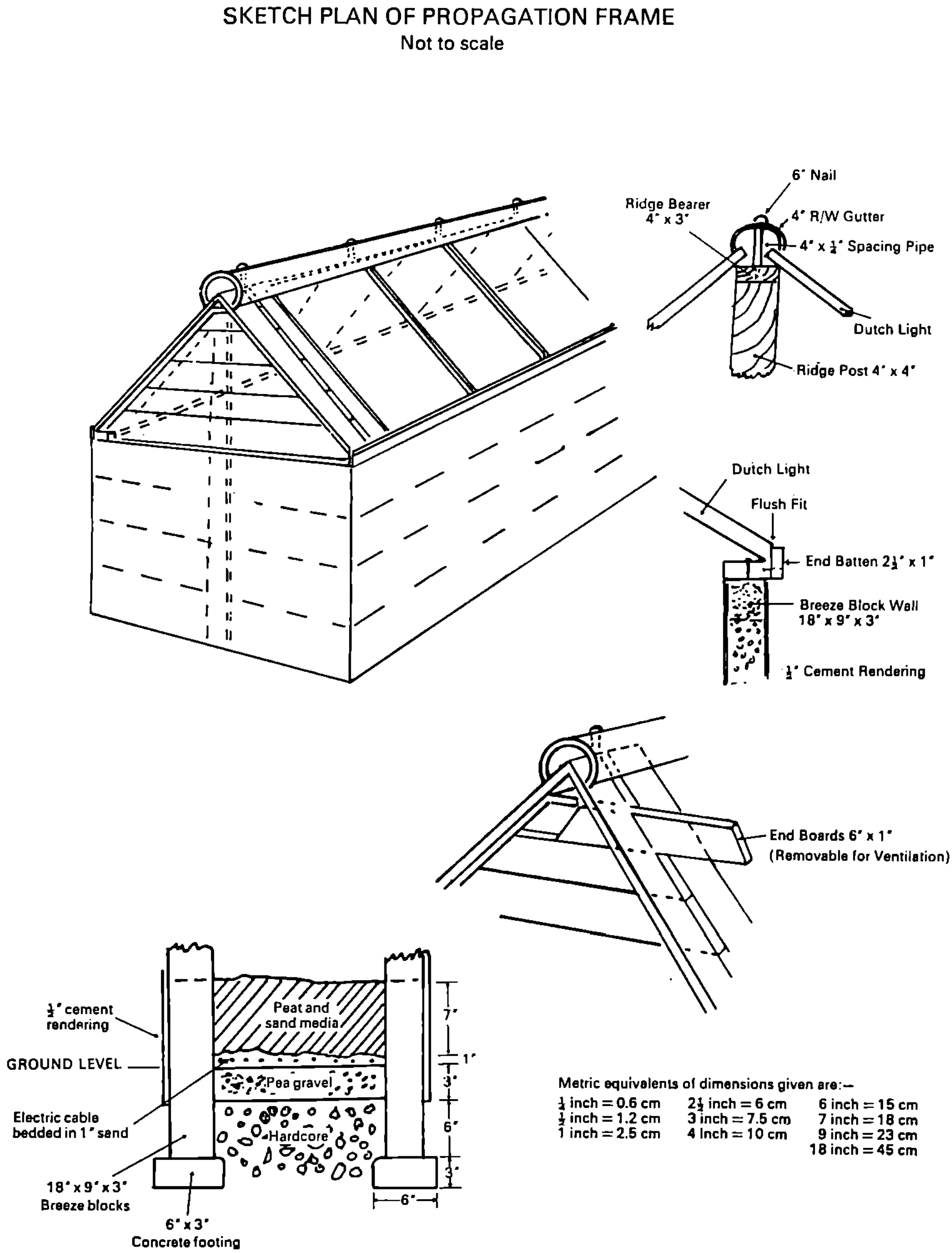



Fig. 5. Propagation frame with soil heating.

a second in October. In a frame where the soil heating provides a maximum heat supply of between 6 and 9 watts per square foot, callousing or rooting takes place in October or November, and April or May but the plants are inactive in the depth of the winter. In frames where the soil heating capacity is 15 watts per square foot, the soil temperature can be kept up during the winter months and the insertion of cuttings delayed until January. This will be an advantage where the frame is used for Leyland cypress only in the first part of the year and then is occupied by cuttings and herbaceous or ornamental species which cannot be cleared until late autumn.

### 12.41 Supply of Leyland Cypress Cuttings

If this hybrid is to be propagated regularly and in large quantities, there should be a plentiful supply of cuttings immediately to hand. Stock plants of whatever clones are to be propagated should be established as a hedge or a small plantation. Best cuttings are obtained from trees between five and fifteen to twenty years old, and new stock plants should be established in good time before the older plants cease to produce the best type of cuttings. If it is necessary to transport material over any distance, whole branchlets should be removed, packed loosely in polythene bags and kept in a cool shady place until required. Branches deteriorate if they have been bruised by being packed tightly into polythene bags for even quite short periods and cuttings taken from them rot. A little straw or dry bracken helps separate branches in a bag and minimises crushing.

### 12.42 Type of Leyland Cypress Cutting

Vigorous current year's shoots without flowers or cones should be selected, taking either laterals 6 to 8 inches/*15 to 20 cm* long or leaders of side branches from 6 to 9 inches/*15 to 22 cm* long without a heel. (Plate 30).

Lateral cuttings should be removed from the parent branch by pulling gently downwards, holding the cutting near the base; they will bring with them a heel of older wood. The heel must then be cut clean with a razor blade or sharp knife at the junction between the base of the young wood and the old. Leaders of side branches are taken without a heel and should be cut with a sharp knife at the junction of the green and brown scale leaves.

### 12.43 When to Take Leyland Cypress Cuttings

For both unheated and heated frames, summer-wood cuttings may be taken between mid-April and the end of May; semi-dormant cuttings may be taken in early October. The best take is obtained from summer wood cuttings.

### 12.44 Preparing Leyland Cypress Cuttings for Insertion

At all times, the aim must be to minimise the period between taking the cutting and its insertion.

First, remove the side shoots from the lower third of each cutting. Then, immediately before insertion, dip just the base of cutting in a root-promoting powder (medium strength indolyl-butyric acid or naphthyl acetic acid) tapping to remove excess powder. Some propagators moisten the base of the cutting before dipping, while others prefer not to moisten, considering that too much powder produces too large a callous and inhibits root initiation. After dipping, the cutting should be inserted in the rooting medium immediately.

### 12.45 Inserting Leyland Cypress Cuttings

The rooting medium should be firm but not compacted. The surface should be levelled and cuttings inserted into small holes made to a third of the length of the cutting with a dibber ⅛ inch/*3mm* in diameter. It is important that the base of the cutting is pushed down to make good contact with the rooting medium. The rooting medium should be pressed around each cutting immediately after insertion. As soon as a batch is in or a section filled, the cuttings should be well watered to firm up the rooting medium around the cutting and to prevent drying out. The cuttings must never be allowed to wilt at any time.

Cuttings should be put in at 2 inches between rows by 1 inch between cuttings/*5 by 2.5 cm*. At this spacing, seventy-two cuttings can be inserted per square foot/*750 per sq metre*.

### 12.46 Propagating conditions for Leyland Cypress

The temperature of the rooting medium should be between 20° and 24°C and the air temperature between 16° and 20°C, i.e. "warm feet, cool heads". After rooting has become quite general (three or four months after insertion), the soil temperature can be reduced to about 18°C to prevent excessive root extension.

The aim when watering is to keep a film of moisture on the foliage. This cuts down transpiration, keeps the leaves turgid and also provides enough moisture in the medium for good root growth. When mist equipment is installed, water is sprayed whenever the controlling electronic leaf dries out. If watering is by hand, a fine-rose watering can should be used and it may be necessary to water several times a day if the weather is very hot.

For the air temperature to be kept low, there must be free ventilation, even to the extent of having no cover at all on warm, windless days. Glass lights should be covered with a thin coating of green "summer cloud" to reduce incoming radiation and hence the rate of evaporation from the foliage of cuttings. This may be essential in nurseries where the water is hard and high rates of evaporation lead to chalky deposits on foliage. A high proportion of cuttings with a heavy deposit of this sort may fail to root.

### 12.47 Yield of Leyland Cypress Rooted Cuttings

In unheated frames, 50 per cent of the Leyland cypress cuttings inserted can be rooted in 12 to 14 months. In heated frames with mist, 50 to 70 per cent of the cuttings can be rooted in three to five months.

### 12.48 Hardening-off Leyland Cypress

Cuttings rooted by early October should be over-wintered in a cold-frame and lined out in the open in the following April or May. Cuttings rooted by the middle of May need to be hardened off in a cold-frame for four to six weeks and lined out in late June or early July.

### 12.49 Lining out Leyland Cypress

All cuttings should be given one full season in the transplant lines before planting in the forest. Plants are fit to plant out when 12 to 16 inches/*30 to 40 cm* in height; if they do not reach this size in one year, they should be wrenched and left for a further season.

## 12.5 Metasequoia glyptostroboides: Dawn Redwood

This species, discovered in 1945 in Western China and introduced into Great Britain in 1949, can be propagated readily in a cold-frame from cuttings being in considerable demand as an arboretum tree.

### 12.51 Type of Cutting: Metasequoia

Vigorous laterals 5 to 8 inches long should be taken with a heel, the thicker the shoots the better. Leaf shoots which have no proper terminal bud and which would normally be shed at the end of the year must be avoided. Young branches formed following pruning in the previous year make particularly suitable cuttings.

### 12.52 Preparation of Metasequoia for Insertion

Remove any leaves on the lower third of the cutting and trim heel with a sharp knife or razor-blade. Dip in a medium strength indolyl-butyric or naphthyl acetic acid rooting powder. It is important not to let cuttings wilt between the time they are removed from the parent tree and when they are inserted in the frame.

### 12.53 Time of Insertion: Metasequoia

Best results are obtained with cuttings taken at the end of June or early July. Such cuttings can be hardened off and will form winter buds by the autumn, when they can if necessary be removed from the frames and transplanted into a sheltered spot in the open. Cuttings may be taken later during the growing season; these are slower to root and normally have to be over-wintered in a hardening-off frame. In the following summer the plants may also need sheltering and watering during hot spells.

Some singling of leaders may be necessary while the plants are in the transplant lines.

## 12.6 Elms

In the past elms have been propagated either from layers, suckers or from seed. More recently, selected clones of elm, some showing both resistance to Dutch Elm disease, *Ceratocystis ulmi*, and desirable timber properties, are now being propagated from cuttings. The best results are obtained with quite soft cuttings and these are very sensitive to drying out. It is therefore essential to have the source of cuttings near at hand, preferably in the form of a stoolbed or cutting bed. The cuttings root quickly and with the best use of the medium two or three batches can be rooted in a summer season.

### 12.61 Type of Elm Cuttings

These should be current year's lateral shoots 5 to 8 inches/*12 to 20 cm* long and without a heel of older wood.

### 12.62 Preparing Elm Cuttings for Insertion

Remove leaves from lower third of the shoot, cut away half of any large leaves remaining to reduce the rate of moisture loss and smooth the heel, removing rough edges with a sharp knife. Dip in a rooting powder containing indolyl-butyric acid or naphthyl acetic acid plus a fungicide.

### 12.63 Rooting Medium for Elms

The first roots formed by cuttings of elm are long, fleshy and brittle; they break very easily when cuttings are removed from the frame. However, root breakage is avoided if individual pots are prepared for each cutting. Peat pots 2½ to 3 inches/*6 to 8 cm* deep, or plastic trays made up of groups of pots 2 inches/*5 cm* across at the top, are both satisfactory.

Whichever type is used should be filled with 50 per cent peat: 50 per cent coarse sand mixture or John Innes No. 1 potting soil. (M.A.F.F. leaflet No. 471. *Seed and Potting Composts*). Cuttings should be inserted to one-third of their length. Pots should be put in the unit so that the surface of the medium in the pot is at the same level, as though cuttings had been inserted direct into rooting medium in the frame.

### 12.64 Time of Insertion: Elms

Best results are obtained with semi-softwood cuttings taken in June or July. Well over 70 per cent of such cuttings have rooted within three weeks. Harder cuttings taken later in the summer root more slowly and are more prone to die back in the winter.

### 12.65 Hardening-off and After-care: Elms

After rooting, pots should be kept in a hardening-off frame for about two weeks after which the rooted elms can be bedded out. Plants should be transplanted in a sheltered situation, and in periods of hot dry weather in the two months after planting out they should be heavily shaded.

In the winter, the rooted cuttings require protection against frost.

## 12.7 Aspen, White and Grey Poplars

Earlier in this chapter, methods were described for rooting dormant hardwood cuttings of black and balsam poplars in the open ground. This method is simple and reliable and should be adopted whenever possible. However a propagating unit is required when clones of aspen, White poplar or Grey poplar (*P. tremula*, *P. alba* and *P. canescens*), have to be raised. As with elm, best results are obtained with soft wood cuttings. These should be taken in early summer from stoolbeds which are cut back annually and which are close to the frame; poplar cuttings root quickly and with the best use of frames it is possible to get three batches rooted in the summer months. The plants in the first batch to be rooted will be biggest at the end of the season but the others will be adequate.

### 12.71 Type of Cuttings: Poplars

These should be 5 inches/*12 cm* long and should be cut with a sharp knife from the top of vigorous, sturdy, current shoots.

### 12.72 Preparation of Poplar Cuttings

Remove leaves from the lower third of the cutting and dip the end in a medium grade rooting powder containing indolyl butyric acid or naphthyl acetic acid.

### 12.73 Rooting Medium and Insertion of Poplar Cuttings

Aspens and Grey and White poplar cuttings should be treated in the same way as has been described above for elms, i.e. inserted into previously prepared peat or plastic pots. Cuttings should be inserted as early as possible in June if the strongest plants are to be obtained by the end of the growing season. Cuttings taken in late June and July will still root but will be smaller at the end of the season.

### 12.74 Hardening-off and After-care: Poplars

This is the same as for elms except that more space should be allowed when the rooted cuttings are transplanted into open ground. They should be set out at not less than 6 by 10 inches/*15 by 25 cm* for the first year and moved again to 15 by 18 inches/*40 by 50 cm* in the second year to permit vigorous growth. Aspens may sometimes take three years to grow to a size fit for forest planting.

#### Further Reading

Bryce, J., 1968. *Cultivation of the Cricket Bat Willow*, 3rd edn., Bulletin No. 17, Forestry Commission, London.

Gray, W. G., 1953. *The Raising of Aspen from Seed.* Forest Record No. 2, Forestry Commission, London.

Jobling, J., 1963. *Poplar cultivation.* Leaflet No. 27, Forestry Commission, London.

Ministry Of Agriculture. 1962. *Seed and potting compost.* Advisory Leaflet No. 471, Ministry of Agriculture, Fisheries and Food, London.

Ovens, H. Blight, W. and Mitchell, A. F., 1964. The clones of Leyland cypress. *Quarterly Journal of Forestry*, Vol. **58**, 8–19.

Peace, T. R., 1952. *Poplars.* Bulletin No. 19, Forestry Commission, London. (out of print).

## APPENDIX I

## STOCKTAKING PROCEDURE

### 1 Objects of the System

The system that follows was designed in 1964 to meet the needs of the Forestry Commission nursery management. In other circumstances, it may *not* meet the needs of the nursery manager, when it should be modified. However, many features of the system are likely to be generally applicable. This 1964 stock-taking procedure:

- (*i*) avoids the practical difficulties such as those encountered when counting a thousand or more plants at a time (e.g. transplants in long lines),
- (*ii*) avoids excessive sampling of "breaks" (clearly defined uniform areas) of seedlings or transplants.
- (*iii*) reduces the overall time taken to take stock.
- (*iv*) reduces the amount of work if a stock count has to be revised.
- (*v*) provides information of known reliability and accuracy (see para 3 below).
- (*vi*) provides more reliable information on seedling yields and transplant survival.

### 2 Outline Procedure

- (*i*) At stocktaking, the total number of seedlings or transplants in selected sample areas is counted; when necessary the height range and the proportion of usable plants are estimated; from these figures, the total number of usable plants is calculated.
- (*ii*) The main stocktaking should be made in August, or as decided by the nursery manager.
- (*iii*) A supplementary stocktaking may be made on breaks to be lifted, but only if more accurate figures are required than have been obtained from the main stocktaking. Supplementary stocktaking should normally be undertaken only after shoot growth has ceased for the season. Supplementary stocktaking will not normally be undertaken on stocks that are to be "stood over" to the next growing season.
- (*iv*) Size of plants and usability. Usability is judged on the basis of the height at the end of the season and the health of stocks. End of season heights should be estimated by eye if plants are still growing or are all usable. Otherwise selected plants in liftable breaks will be measured.

### 3 Accuracy of Stocktaking

The intensity of sampling prescribed in this procedure is designed to provide information of known accuracy. To amplify this statement, it must be explained that whenever *samples* are counted or measured (instead of counting or measuring *all* plants), the answer calculated from the sample assessments will very seldom equal the correct answer, the difference being termed the "sampling error." This "sampling error" can be expressed as a *range* within which the correct answer *probably* lies. In this stocktaking procedure, the sampling is so designed that the true number of plants from the main stocktaking should be within $\pm$ 10 per cent (*range*) of the number calculated from the samples, nineteen times out of twenty (*probability*), and to be within $\pm$ 5 per cent (*range*) nineteen times out of twenty (*probability*) for the supplementary stocktaking. It should be noted that the range of the sampling error of the supplementary stocktaking should be half that of the main stocktaking for the same probability, but that to halve the sampling error in this way, four times more samples are required in a supplementary stocktaking than in the corresponding main stocktaking.

### 4 Uniformity Test

Provision is made after the first part of the main stocktaking for a test of the uniformity of the break to indicate whether further samples have to be counted before the main stocktaking is complete. The check is a simplified statistical test of the spread of results from individual sample counts around the mean. The result of the check is also the basis for sampling in any supplementary stocktaking.

### 5 Size of Plants

Various systems of recording the size of plants have been used in recent years. The system used here specifies that the sizes given should be as descriptive as possible, and should indicate the range of height in inches which includes the bulk of the plants. Thus in a batch of Scots pine transplants described as 7–11 inches (*or 15–25 cm*) one would expect to find about 80 per cent actually in that size range, a few plants (about one in ten) below the lower limit and also a few plants (about one in ten) above the upper limit. Where transplants are marked for grading, for example 'RLO' and 'F', or for two different sizes of planting stock, the size markings should show the grading limit, e.g. 3–6 in (*8–16 cm*) and 6–10 in (*16–25 cm*) or 8–11 in (*20–27 cm*) and over 11 in (*over 27 cm*).

### 6 Special Stocks

Often there will be a few breaks of plants in a nursery which have been sown or planted for special reasons. In such cases, knowledge of the stock present may be much less or much more important than for the general run of nursery stock. The nursery forester must in these cases use his common sense as to the accuracy required in taking stock.

### 7 Definition of Terms

- (*i*) A **'break'** is an area within one nursery section containing stock of a single species, identity number, type and (in the case of transplants graded at lining-out) grade, and in which no patches of obviously different stocking or height growth individually exceed 100 square yards/*100 sq m*. If such patches exceed 100 square yards/*100 sq m*, they are to be treated as a separate break or breaks.

(*ii*) **Size of plants** is to be expressed as a range of heights in inches/*cm* containing 80 per cent (or more) of the plants in a break. About 10 per cent of the remainder may be expected to be over the range indicated and about 10 per cent under. In any break to be lifted, the sizes given refer to the *usable* plants.

(*iii*) **'Total' plants** include *all* plants alive at the time of the count (main or supplementary). *This total includes plants expected to be culls.*

(*iv*) **'Remain'** seedlings are those not recommended for lifting. Plants within this category are to be classified into:

**'SO' seedlings**—plants suitable for standing over and not suitable either for lining-out or for undercutting for planting stock.

**'UC' seedlings**—plants not intended for lining-out, but which are suitable and intended for undercutting *to produce forest planting stock in the following year.*

(*v*) **'Use' seedlings** are those suitable for lifting. Plants in this category are to be classified into:

'LO' seedlings—plants suitable for lining-out.

'F' seedlings—plants suitable for forest planting; such plants will normally be two-year-old seedlings which have been sown at low density and undercut.

(*vi*) **'SO' transplants** are those suitable for standing over and not suitable for use in the forest or for relining-out.

(*vii*) **'Use' transplants** are those suitable for lifting. Plants in this category will be classified into:

'F'—plants suitable for use in the forest.

'RLO'—plants suitable for relining-out.

## 8 Procedure

For the main and supplementary stocktaking the same sequence of operations will be followed for each break of seedbeds or transplants. This sequence is:

(*i*) *Preparations:*

Determine:

(*a*) The total length of bed, or number and/or length of lines.
(*b*) The size of samples.
(*c*) The number of samples to be assessed.
(*d*) The distance between samples (and the number of beds to be sampled in large breaks).

(*ii*) *Sampling:*

(*a*) Count of all living plants within samples.
(*b*) Number and size of usable plants.

(*iii*) *Calculations:*

(*a*) Total stock.
(*b*) Usable stock.
(*c*) Uniformity check (main stocktaking only).

Where only size and usability have to be revised, some of the above operations are omitted.

*See also para.* 20, "*Worked Examples*", *on page 137.*

## 9 Seedbeds—Main Stocktaking

(Seedlings sown for undercutting to produce forest planting stock will be counted in the same way as seedlings sown to produce transplanting stock).

(*i*) PREPARATIONS

(*a*) *Total length of bed*

Calculate in yards/metres the total length of seedbeds in a break.

(*b*) *Size of sample unit*

The sample area will cover the full width of the bed. The size of the sample unit along the bed depends on a preliminary judgement of the stocking of the break and is chosen to include an adequate number of plants per sample. Where drills are sown across the bed, each sample will be one or more drills as given in Table 35a, page 132. For all other beds, sample areas will be defined by metal grids (shown in Fig. 6, page 131), of a size given in Table 35a.

(*c*) *Number of samples to be assessed*

In all except very small breaks, the number of samples required is obtained from the preliminary judgement of stocking using Table 35a. In very small breaks a lower precision is generally tolerable, and a minimum distance between samples is therefore prescribed in Table 35a instead of a fixed number of samples.

(*d*) *Distance between samples*

In many breaks the best procedure will be to space the samples regularly down each bed by calculating the distance between samples as the total length of bed divided by the number of samples. In large breaks this will require too much walking between samples and may also result in an unrepresentative distribution of samples. To avoid these difficulties it is suggested that the distance between samples in a bed should not be much more than 20 yards/*20 m*. If the distance calculated by dividing the total length of bed by the number of samples exceeds 20 yards/*20 m*, only two beds out of every three, or one out of every two, three or four, etc. need be sampled. The number of beds to be sampled should be the greatest number which gives a sampling interval of 20 yards/*20 m* or less. For example a break of 19 beds each 80 yards/*80 m* long requiring 60 samples, would have 12 beds sampled with five samples per bed, i.e. two beds out of three would be sampled with a sampling interval of 16 yards/*16 m*.

The first sample should be taken at one half the distance between samples from the end of the first sampled bed.

(*ii*) SAMPLING

(*a*) *Counts*

*All* living seedlings falling within a sample area will be counted. The distance between samples may be measured by pacing or by tape, but no latitude is allowable in placing the sampling

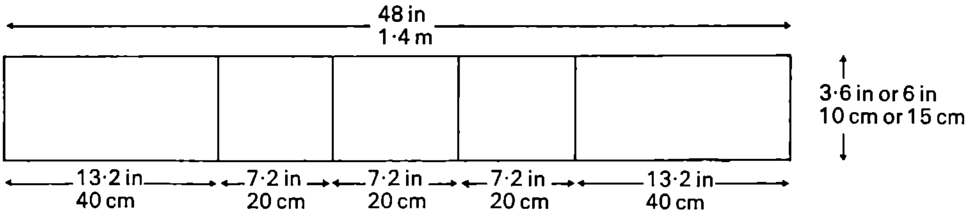



Fig. 6. Seedbed grids.

*Note:* The grid should be marked with a spot of paint at intervals of 8 inches on a 48-inch grid/*17.5 cm on a 1.4 m grid.* The seedlings nearest each of these marks should be measured for height, or classified for usability if required.

frame; it must be placed so that the nearer edge comes at the point indicated by measurement.

(*b*) *Number and size of usable seedlings—liftable beds only*

Where plants are still growing and may put on sufficient growth between the time of the stocktaking and the end of the season to alter the proportion of usable plants to any important extent, the forester will estimate both expected height range and the proportion of the seedlings expected to be usable at the end of the season.

Where plants have effectively stopped growing in height for the year, and more than 95 per cent are usable and no grading is proposed, the forester will estimate the height range of the seedlings.

Where plants have effectively stopped growing in height, and either less than 95 per cent are usable or grading is proposed, in beds sown broadcast or in drills sown *across* the bed, the seedling nearest each of the five predetermined positions (see Fig. 6) on the sampling frame will be classified as unusable or usable and, if necessary, usable plants will be measured for height. In beds sown in drills *along* the bed, the seedling in each drill nearest one side of the sampling frame will be assessed. Heights will normally be measured to the nearest inch, but if the height range is very large, measurements to the nearest 2 or 3 inches may suffice. When using metric units, it will probably be most convenient to measure to the nearest 2 cm for most stock and to the nearest 5 cm where the height range is larger.

(*iii*) CALCULATIONS

(*a*) *Total number of seedlings in a break*

Total number of seedlings in a break =

$$\frac{\text{Total count from all samples} \times g \times \text{total length of bed in yards}/m}{\text{Number of samples}}$$

*NOTE: g* is a multiplying factor depending on the size of grid as set out below:

*Seedbeds measured in yards*

Where a 3.6 inch grid is used, $g=10$.
Where a single 6 inch grid is used, $g=6$.
Where a 12 inch (double 6 inch) grid is used, $g=3$.
Where drills are sown across the bed, $g=$ 36 ÷ (distance in inches between drills × number of drills in a sample).

*Seedbeds measured in metres*

Where a 10 cm grid is used, $g=10$.
Where a single 15 cm grid is used, $g=6.7$.
Where a 30 cm (double 15 cm) grid is used, $g=3.3$.
Where drills are sown across the bed, $g=$ 100 ÷ (distance in cm between drills × number of drills in a sample).

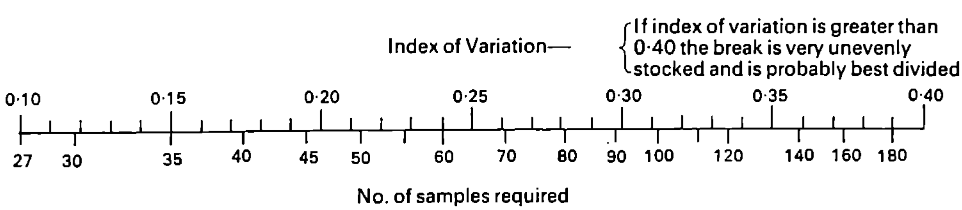



Fig. 7. Uniformity Chart for seedbeds.

TABLE 35

STOCKTAKING—SAMPLE SIZE PER BREAK

(*a*) SEEDBEDS

| Preliminary judgement of density per yard/*metre* run | Size of sample unit | No. of samples required | Minimum distance between samples for small (breaks) |
|---|---|---|---|
| **CONIFERS** | | | |
| more than 1000<br>600 to 1000<br>400 to 600<br>200 to 400 | 3.6 in/10 cm grid or 1 drill | 30<br>40<br>60<br>80 | 2 yd/*2 m* |
| 100 to 200<br>50 to 100 | 6 in/*15 cm* grid or 2 drills | 80<br>100 | 3 yd/*3 m* |
| less than 50 | 12 in/*30 cm* grid* or 3 drills | 100 | 5 yd/*5 m* |
| **HARDWOODS** | | | |
| more than 100<br>50 to 100 | 6 in/*15 cm* grid or 2 drills | 80<br>100 | 3 yd/*3 m* |
| less than 50 | 12 in/*30 cm* grid* or 3 drills | 100 | 5 yd/*5 m* |

*For a 12 in/*30 cm* grid use two adjacent positions of 6 in/*15 cm* grid.

(*b*) TRANSPLANTS

| | | | |
|---|---|---|---|
| **SIZE OF SAMPLE UNIT** | | | |
| Short lines across beds<br>Long lines | One line<br>Less than 3 in/*7.5 cm* spacing—1 yard of line<br>3 in/*7.5 cm* spacing or more—2 yards of line<br>*1 m, 2 m of line respectively.* | | |
| **NO. OF SAMPLES REQUIRED** | | | |
| | PRELIMINARY JUDGEMENT OF SURVIVAL PERCENT | | |
| All arrangements | more than 75%<br>30 samples | 60%—75%<br>50 samples | less than 60%<br>80 samples |
| **SAMPLING INTERVAL IN VERY SMALL BREAKS** | | | |
| Short lines<br>Long lines in beds<br>Long lines not in beds | Every 20 lines<br>Every 3 yd/*3 m* down the bed<br>Every 20 yd/*20 m* down each line | but not less than 10 samples | |

(*b*) *Usable stock* (*liftable beds only*)

Where seedlings are measured for height and usability: Usable stock =

$$\frac{\text{Number of usable seedlings measured} \times \text{Total number of seedlings in break}}{\text{Total number of seedlings measured}}$$

Where height and usability are estimated by the forester: Usable stock=

$$\frac{\text{Estimated per cent usable} \times \text{Total number of seedlings}}{100}$$

At certain nurseries where losses due to disease, frost, and possibly lifting operations are to be expected, the forester may, at his own discretion, reduce the number of usable seedlings by not more than 5 per cent. If he expects greater losses than this between stocktaking and lifting, he must agree a figure with the nursery manager.

(*c*) *Uniformity check*

Except in standover beds and in small breaks in which samples were taken at the sampling interval given in the last column of Table 35a, an "Index of Variation" should be calculated as below, and used to determine whether the number of samples taken is adequate. If the number of samples is insufficient to give the required accuracy, the "Index of Variation" determines the number of extra samples required. The procedure is:

(1) Calculate the average number of seedlings per sample in the main count.
(2) Multiply the average number of seedlings per sample by 0.7.
(3) Find how many of the samples had fewer seedlings than 0.7 of the average (the figure calculated in the previous step).
(4) Divide this number by the total number of samples to obtain the "Index of Variation."
(5) Using Fig. 7, page 131, find the "Index of Variation" obtained in step 4 on the upper scale of the chart, and read from the lower scale the number of samples that should have been taken in the main stocktaking.
(6) If this number is no more than 20 per cent greater than the number of samples actually taken, no further samples need be measured in that break. If the number of samples found from the chart is more than 20 per cent over the number of samples actually counted, the main stocktaking cannot be considered completed until the extra samples (the number shown on the chart, less the number already counted) have been counted.

If further samples are found necessary, use the procedure given under paras. 9 (*i*) and (*ii*) to assess the additional samples. The results of such further sampling will be combined with the previous results and revised Total and Usable stock figures calculated (see Table 36, page 138, for a tabular aid to calculations and Table 37, page 139 for worked example).

### 10 Seedbeds—Separate Size/Usability Assessment

A size/usability assessment separate from the main stocktaking may be made if for any reason the grading or the proportion of usable plants has to be revised, and the figures for the total number of seedlings in a break obtained from the main stocktaking are valid and sufficient.

Where more than 95 per cent of the seedlings are usable and no grading is proposed, the forester will estimate the height range of the plants by eye. Where less than 95 per cent are usable, or grading is proposed, the procedure below will be followed:

( *i* ) PREPARATIONS

(*a*) *Total length of bed*
Check the figure previously calculated for the main count.

(*b*) *Number of samples*
30 samples per break.

(*c*) *Distance between samples*
The distance between samples and the number of beds to be sampled are determined as in para. 9 (*i*) (*d*).

(*d*) *Size of sample*
In beds sown broadcast or in drills sown *across* the bed, the seedling nearest each of the five pre-determined positions (see Fig. 6) on the sampling frame will be classified for usability and, if necessary, usable plants will be measured for height. In beds sown in drills *along* the bed, the seedling in each drill nearest one corner of the sampling frame will be assessed.

( *ii* ) SAMPLING

At each sampling point, a seedbed sampling frame will be put down and the seedlings nearest the five positions defined in para 10 (*i*) (*d*) classified as usable or unusable; the height of the usable seedlings will be measured if required to the nearest 2 or 3 inches/2 *or* 5 *cm*.

( *iii* ) CALCULATIONS

The figures obtained from the sampling will be used to revise the calculation shown at para 9 (*iii*) (*b*).

### 11 Seedbeds—Supplementary Stocktaking

A supplementary stocktaking will be made only if nursery managers require more precise figures than are provided by the main stocktaking.

( *i* ) PREPARATIONS

(*a*) *Total length of bed*
Check the figure previously calculated for the main stocktaking.

(*b*) *Size of sample*
As for the main stocktaking (para 9 (*i*) (*b*)).

(*c*) *Number of samples to be assessed*
Multiply by 4 the revised number of samples calculated using the "Index of Variation" to be required for the main stocktaking (para 9 (*iii*) (*c*)). This is the number of samples required for the supplementary stocktaking.

If the number of samples to be assessed is *the same as or less than* the number already actually assessed in the main stocktaking and there has been no change in the health or survival of seedlings, the total number of seedlings from the main stocktaking may be accepted as the total number for the supplementary stocktaking.

(*d*) *Distance between samples*
The distance between samples and the number of beds to be sampled are determined as in para 9 (*i*) (*d*).

(*ii*) SAMPLING
*Counts and size/usability estimates*
As for the main stocktaking (paras 9 (*ii*) (*a*) and (*b*) except that the size/usability assessment need be made in only a quarter of the sample areas.

(*iii*) CALCULATIONS
As for the main stocktaking except that no check on the number of samples is required (paras 9(*iii*)(*a*) and (*b*)).

**12 Transplants—Main Stocktaking**

(*i*) PREPARATIONS
The sampling of transplants differs in detail according to spacing and whether transplants have been lined-out in:
Short lines across beds.
Long lines with a regular number of lines per bed (usually between 5 and 7).
Long lines not arranged in beds.

*A. Short lines across beds*

(*a*) *Number of lines in break*
Calculate the total number of lines in a break.

(*b*) *Size of sample unit*
The sample unit is one line of plants.

(*c*) *Number of samples to be assessed*
In all except very small breaks, the number of samples required is obtained from a preliminary judgement of the survival per cent and Table 35b, page 132. In very small breaks, less accuracy is generally required and a minimum interval between samples is therefore prescribed in Table 35b instead of a fixed number of samples. The method requiring the least work should be followed.

(*d*) *Distance between samples*
The distance between samples in a bed should not be much more than 20 yards/*20 m* (see para 9 (*i*) (*d*)). If the distance calculated by dividing the total length of bed by the number of samples exceeds 20 yards/*20 m*, only two beds out of every three or one out of every two, three, four etc., need be sampled. The number of beds to be sampled should be the greatest number which gives a sampling interval of 20 yards/*20 m* or less. (For an example see para 9 (*i*) (*d*)). The first sample should be taken at one half the distance between samples from the end of the first sampled bed.

*B. Long lines in beds*

(*a*) *Length of bed*
Calculate the total length of bed.

(*b*) *Size of sample unit*
See Figure 8 for measuring stick.

Where spacing between plants is less than 3 inches/*7.5 cm*, the sample unit is one yard/*1 m* run along one line of transplants; where it is 3 or more inches/*7.5 or more cm*, the sample unit is a 2 yard/*2 m* run.

(*c*) *Number of samples to be assessed*
The number of samples required is obtained as described for short lines across beds. If however, the number of samples based on the preliminary judgement of survival per cent is not a multiple of the number of lines in a bed, take the nearest multiple, e.g. if there are 6 lines in a bed and the number of samples indicated by Table 35b is 50, take 48 as the number of samples required.

The 1st sample is taken in the 1st line of the bed, the 2nd in the 2nd line at the next sample position, the 3rd sample in the 3rd line, and and so on.

(*d*) *Distance between samples*
See para 12 (*i*) (*d*).

*C. Long lines not arranged in beds*

If possible, treat the break as though in beds of a regular number of lines (para 12 (*i*) (*b*)). If this is not justifiable, proceed as below:

(*a*) *Length of line*
Calculate the total length of line.

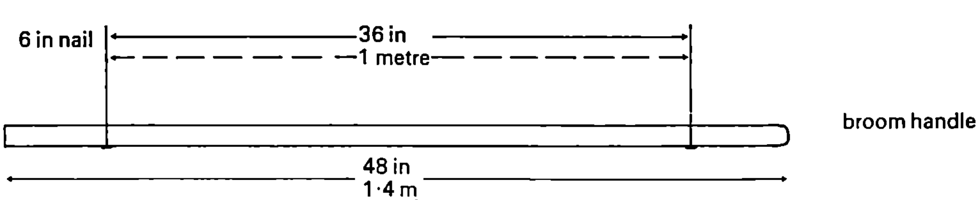



Fig. 8. Measuring stick for transplant lines.

(*b*) *Size of sample unit*
Where the spacing between plants is less than 3 inches/*7.5 cm*, the sample unit is one yard/*1 m* run along one line of transplants; where it is 3 inches/*7.5 cm* or more, the sample unit is a 2 yard/*2 m* run.

(*c*) *Number of samples to be assessed*
In all except very small breaks it should be possible to treat the break as though in beds of a regular number of lines. For very small breaks a minimum distance between samples is prescribed in Table 35b. The method requiring the least work should be followed.

(*d*) *The distance between samples*
For breaks treated as though in beds, para 12(*i*)(*d*) applies. For other breaks the distance between samples is the total length of lines divided by the number of samples to be taken. The distance to the first sample from the beginning of the first line of plants should be half the distance between all subsequent samples.

( *ii* ) SAMPLING

(*a*) *Counts*
All living plants in a sample will be assessed.

(*b*) *Number and size of usable plants—liftable breaks only*
Where transplants are still growing and may put on sufficient growth between the time of the stocktaking and the end of the growing season to alter the proportion of usable plants to any important extent, the forester will estimate by eye the expected height range and the proportion of the transplants expected to be usable at the end of the season.

Where plants have effectively stopped growing, more than 95 per cent are usable and no grading is proposed, the forester will estimate their height range by eye.

Where plants have effectively stopped growing and either less than 95 per cent of the transplants are usable or grading is proposed, six living transplants per sample will be classified as unusable or usable and if necessary, the usable plants among them will be measured for height. In short lines, six adjacent living transplants will be assessed beginning at one end in the first sample line, one foot from the same end in the second, two feet in the third sample line, and so on, reverting to the beginning after every six lines. In the event of fewer than six living transplants occurring in the sample line, living transplants in the next line or lines should be measured. In long lines, the first six living transplants will be measured from one end of each yard run sampled.

( *iii* ) CALCULATIONS

(*a*) *Total stock*

*For short lines,*

Total stock =

$$\frac{\text{Total number of lines} \times \text{Sum of all plants counted}}{\text{Number of samples counted}}$$

*For long lines in beds,*

Total stock =

$$\frac{\text{Total length of beds in yards/}\textit{metres} \times \text{Sum of all plants counted} \times \text{the Number of lines in each bed}}{\text{Number of samples} \times l}$$

*For long lines not in beds,*

Total stock =

$$\frac{\text{Total length of line in yards/}\textit{metres} \times \text{Sum of all plants counted}}{\text{Number of samples counted} \times l}$$

$l$ is a factor depending on the length of the sample unit.
Where the sample is a one yard/*metre* run, $l=1$.
Where the sample is a two yard/*metre* run, $l=2$.

(*b*) *Usable stock*

*Liftable breaks only*

Where the height and usability of plants has been measured:
Usable stock =

$$\frac{\text{Number of plants classed as usable} \times \text{Total stock}}{\text{Total number classified}}$$

Where height and usability of plants are estimated by the forester:
Usable stock =

$$\frac{\text{Estimated percentage usable} \times \text{Total stock}}{100}$$

At certain nurseries where losses due to disease, frost, and possibly lifting operations are to be expected, the forester may, at his own discretion, reduce the number of usable transplants by not more than 5 per cent. If he has reason to expect greater losses than this between stocktaking and lifting, he must agree a figure with the nursery manager.

(*c*) *Uniformity check*

*Liftable breaks only*
As for seedlings (para 9 (*iii*) (*c*)), except that Fig. 9, p. 136, is used instead of Fig. 7 (see Table 37, pp. 141–143 for worked examples).

**13 Transplants—Separate Size/Usability Assessment**

A size/usability assessment separate from the main stock-taking may be made if for any reason the grading or the

UNIFORMITY CHECK–TRANSPLANTS

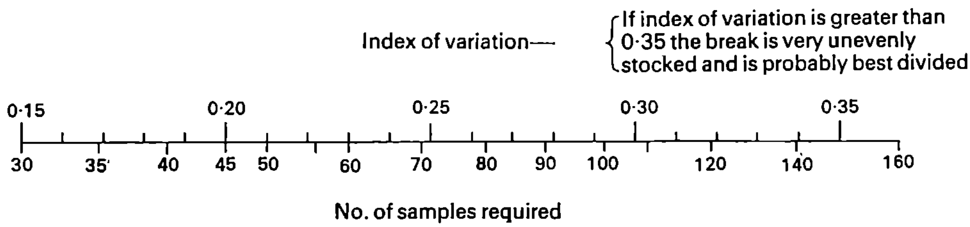



Fig. 9. Uniformity chart for transplant beds.

proportion of usable plants has to be revised while the figures for the total number of transplants in a break obtained from the main stocktaking are valid and sufficient. Where more than 95 per cent of the plants are usable and no grading is proposed, the forester will estimate the height range by eye. Where less than 95 per cent are usable or grading is proposed, the procedure below should be followed:

(*i*) PREPARATIONS

(*a*) *Total length of bed*
Check the figure previously calculated for the main stocktaking.

(*b*) *Size of sample*
The first six live plants in a line, starting from the sampling point.

(*c*) *Number of samples*
25 samples per break, or the next higher multiple of the number of lines in a bed.

(*d*) *Distance between samples*
Calculate this as described for the main stocktaking in para 12 (*i*) according to the pattern of lining-out.

(*ii*) SAMPLING
Plants in each sample will be classified into usable and unusable, and the usable plants measured for height to the nearest 1, 2 or 3 inches/*2 or 5 cm.*

(*iii*) CALCULATIONS
The figures obtained will be used to revise the calculation shown in para 12 (*iii*) (*b*).

**14. Transplant Lines—Supplementary Stocktaking**

A supplementary stocktaking will be made only if the nursery manager requires more precise figures than are provided by the main stocktaking.

(*i*) PREPARATIONS

(*a*) *Number or length of lines or number of beds*
Check the figure previously calculated for the main stocktaking.

(*b*) *Size of sample unit*
As for the main stocktaking according to the pattern of lining-out (para 12).

(*c*) *Number of samples to be assessed*
Multiply by 4 the revised number of samples calculated using the "Index of Variation" to be required for the main stocktaking (para 12 (*iii*) (*c*)). This is the number of samples required for the supplementary stocktaking.

If the number of samples to be assessed is *the same as or less than* the number already actually assessed in the main stocktaking and there has been no change in the health or survival of transplants, the total number of transplants from the main stocktaking may be accepted as the total number for the supplementary stocktaking.

(*d*) *Distance between samples*
As for the main stocktaking, according to pattern of lining-out.

(*ii*) SAMPLING
*Counts and assessments of size/usability*
As for main stocktaking (paras 12 (*ii*) (*a*) and (*b*)).

(*iii*) CALCULATIONS
As for the main stocktaking except that no uniformity check is required (para 12 (*iii*) (*a*) and (*b*)).

**15 Stock Returns**

All the records and calculations prescribed above should be made on the nursery stocksheets.

The results of the main stocktaking should be summarised showing 'Total', 'SO'. 'UC', 'LO', 'RLO', or 'F' as appropriate in separate columns.

The results of supplementary stocktaking should be notified to nursery managers in whatever manner most conveniently meets local needs.

## 16 Worked Examples

Worked examples of seedbed and transplant assessment data, recorded on standard Forestry Commission forms, are given in table 37. These data are worked up to show how the number of plants in the break is derived from the original counts.

CALCULATION PROCEDURE—USE OF TABULATIONS IN TABLES 36(a) AND (b).

Tables 36(a) and (b) are intended as calculation aids to be used in the nursery office when working up figures from the actual counts taken to obtain the total number of plants for any given break. The sequence in Table 36(a) is used in conjunction with the *seedbed* stocktaking forms illustrated in examples 1 and 2, Table 37, pp. 139 & 140.

The sequence in Table 36(b) is used in conjunction with *transplant* stocktaking forms illustrated in examples 3, 4 and 5, Table 37, pp. 141–143.

Both tables must be available on card or stiff paper, the lines typed or printed at a spacing which coincides exactly with the line spacing on the left-hand side of the stocktaking forms.

In use, for seedbeds, Table 36(a) is placed on the left-hand side of the seedbed stocktaking form, so that the letters on the right-hand margin of Table 36(a) agree with those on the left-hand margin of the stocktaking form. The individual calculations steps laid out on Table 36(a) are then followed one by one down the page. The answers should be written in the appropriate space in the "calculations (i)" or "calculations (ii)" columns on the stocktaking form.

Table 36(b) should be used similarly for transplants.

TABLE 36 STOCKTAKING—AIDS TO CALCULATION

(*a*) SEEDBED CALCULATION SEQUENCE

| | | |
|---|---|---|
| C | Total count; from r.h. side | C |
| N | No. of samples counted; from r.h. side | N |
| A | Average count; C ÷ N | A |
| g | Grid factor; see * below | g |
| D | Density (No. per yard/*metre* run); A × g | D |
| L | Total length of beds (yd/*m*); from r.h. side | L |
| T | Total No. of seedlings (thous.); D × L ÷ 1000 | T |
| F | A × 0.7 | F |
| n | No. of sample counts less than .7A; count on r.h. side | n |
| V | Index of variation; n ÷ N | V |
| R | Revised No. of samples required; from Fig. 7 | R |
| N/5 | N ÷ 5 | N/5 |
| R–N | Additional samples required; if (R–N) more than (N/5) | R–N |
| | | |
| S | Size of grade (80% height range); from l.h. side | S |
| t | Total plants assessed; from l.h. side | t |
| u | No. of usables measured in grade; from l.h. side | u |
| P | Proportion usable; u ÷ t | P |
| Use | Usable stock (thous.): P × T | Use |

*Beds measured in yards:*
* 'g' = 10, if a 3.6 inch sample grid is used.
= 6, if a 6 inch sample grid is used.
= 3, if a double 6 inch grid is used.
= 36 ÷ (distance between drills in inches × No. of drills in sample unit) if drill sown.

*Beds measured in metres:*
'g' = 10, if a 10 cm sample grid is used.
= 6.7, if a 15 cm sample grid is used.
= 3.3, if a 30 cm sample grid is used.
= 100 ÷ (distance between drills in cm × No. of drills in sample unit) if drill sown.

(*b*) TRANSPLANT CALCULATION SEQUENCE

| | | | |
|---|---|---|---|
| C | Total count; from r.h. side | | C |
| N | No. of samples counted; from r.h. side | | N |
| A | Average count; C ÷ N | | A |
| L | Total No. of lines | from r.h. side | L |
| L | or total length of beds | from r.h. side | L |
| L | or total length of lines | from r.h. side | L |
| T | Total No. of transplants (thous.); A × L ÷ ('1'* × 1000) | | T |
| O | Total No. lined-out (thous.); from P.S.5 | | O |
| AS% | Average survival %; 100 × T ÷ 0 | | AS% |
| F | A × 0.7 | | F |
| n | No. of sample counts less than .7A; count on r.h. side | | n |
| V | Index of variation; n ÷ N | | V |
| R | Revised No. of samples required; from Fig. 9 | | R |
| N/5 | N ÷ 5 | | N/5 |
| R–N | Additional samples required if (R–N) more than (N/5) | | R–N |
| | | | |
| S | Size of grade (80% height range); from l.h. side | | S |
| t | Total plants assessed; from l.h. side | | t |
| u | No. of usables measured in grade; from l.h. side | | u |
| P | Proportion usable; u ÷ t | | P |
| Use | Usable stock (thous.); P × T | | Use |

* '1' is a line sample factor where:
'1' = 1 for short lines across beds.
= 1 for samples one yard/*metre* long in long lines
= 2 for samples two yards/*2 metres* long in long lines.

TABLE 37

WORKED EXAMPLES OF STOCK SHEETS WITH EXPLANATORY NOTES

# EXAMPLE 1

## SEEDBED STOCKTAKING

Beds: Average length 120 yds. No. 10
Total length of bed 1200 yds.
Preliminary estimate of Stocking per unit run of bed 300
Size of sample unit 3' 6"
No. of samples 80 + 30 Distance between samples (15/20) yds. in (18/5) beds

Main/~~Supplementary~~ count 14/8/70
Species SS
Identity No. 63 (7111)
Age 1+0 Section No. 2
Area of break 2200 sq. yds.

| | CALCULATIONS (1) | (2) |
|---|---|---|
| C | 2379 | 3206 |
| N | 80 | 110 |
| A | 29·7 | 29·1 |
| g | 10 | |
| D | 297 | 291 |
| L | 1200 | |
| T | 357 | 349 |
| F | 20·8 | |
| n | 26 | |
| V | ·325 | |
| R | 110 | |
| N:S | 16 | |
| R·N | 30 | |
| | USABLES | |
| S | 2-5 | |
| t | | |
| u | | |
| P | ·9 | |
| Use | 314 | |

| HEIGHT AND USABILITY CLASSIFICATION: Height Class/Unit | Tally | No. of plants in Class |
|---|---|---|
| | | |
| Unusables | | |
| Total plants measured (1) | | |

SUMMARY OF STOCKS

| Total Stock (T) | REMAIN SO | REMAIN UC | USE LO | | USE F | |
|---|---|---|---|---|---|---|
| thous | thous | thous | thous | size | thous | size |
| 349 | | | 314 | 2-5 | (August guess) | |

SAMPLE COUNTS (all living plants)

| | | | | | | | | | | | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 15 | 9 | 28 | 48 | 37 | 30 | 44 | 9 | 28 | 39 | 325 |
| 2 | 25 | 24 | 34 | 25 | 49 | 59 | 36 | 20 | 24 | 31 | 305 |
| 3 | 42 | 38 | 49 | 30 | 38 | 34 | 45 | 12 | 31 | 17 | 354 |
| 4 | 51 | 45 | 24 | 21 | 22 | 40 | 21 | 19 | 35 | 24 | 240 |
| 5 | 17 | 52 | 36 | 8 | 16 | 58 | 5 | 11 | 26 | 22 | 272 |
| 6 | 49 | 40 | 12 | 15 | 21 | 41 | 58 | 15 | 19 | 27 | 428 |
| 7 | 33 | 35 | 48 | 16 | 40 | 64 | 16 | 18 | 21 | 21 | 282 |
| 8 | 46 | 14 | 50 | 15 | 23 | 36 | 14 | 26 | 37 | 28 | 173 |
| 9 | 28 | 20 | 52 | 22 | 12 | 32 | 33 | 17 | 43 | 30 | 293 |
| 10 | 19 | 28 | 21 | 40 | 14 | 34 | 10 | 26 | 29 | 25 | 264 |
| | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | |
| 1 | 27 | | | | | | | | | | 270 |
| 2 | 23 | | | | | | | | | | |
| 3 | 45 | | | | | | | | | | |
| 4 | 18 | | | | | | | | | | |
| 5 | 36 | | | | | | | | | | |
| 6 | 15 | | | | | | | | | | |
| 7 | 40 | | | | | | | | | | |
| 8 | 25 | | | | | | | | | | |
| 9 | 22 | | | | | | | | | | |
| 10 | 19 | | | | | | | | | | |
| | 110 | 120 | 130 | 140 | 150 | 160 | 170 | 180 | 190 | 200 | |

Revised Total Count (2) 3206 Total Count (1) 2379

EXAMPLE 1

A seedbed count where the first count based on 80 samples revealed that beds were not sufficiently uniform, so that 30 more samples were required. The figures encircled are all those in the first 80 samples which were less than 20.8 (Av. number per sample × 0.7).

No assessment of height was considered necessary. The size and proportion of usable stock were estimated.

*Table* 37—*continued.*

# EXAMPLE 2

## SEEDBED STOCKTAKING

| | CALCULATIONS (1) | (2) |
|---|---|---|
| C | 1987 | |
| N | 80 | |
| A | 24·8 | |
| g | 6 | |
| D | 149 | |
| L | 570 | |
| T | 85 | |
| F | 17·3 | |
| n | 6 | |
| V | ·075 | |
| R | | |
| N/S | | |
| R·N | | |

| HEIGHT AND USABILITY CLASSIFICATION | | |
|---|---|---|
| Height Class/Unit Inches | Tally | No. of plants in Class |
| 6 | | 38 |
| 7 | | 89 |
| 8 | | 103 |
| 9 | | 79 |
| 10 | | 62 |
| 11 | | 27 |
| 12+ | | 47 |
| | | 445 |
| Unusables | | 35 |
| Total plants measured (t) | | 480 |

| | USABLES |
|---|---|
| S | 7-12 |
| t | 480 |
| u | 445 |
| P | ·927 |
| Use | 78 |

| SUMMARY OF STOCKS | | | | | | |
|---|---|---|---|---|---|---|
| Total Stock (T) | REMAIN | | USE | | | |
| | SO | UC | LO | | F | |
| thous | thous | thous | thous | size | thous | size |
| 85 | | | | | 78 | 7-12 |

Beds: Average length 50 yds. No. 11
Total length of bed 550+20 = 570 yds.
Preliminary estimate of Stocking per unit run of bed 150
Size of sample unit 6"
No. of samples 80 Distance between samples 7 yds. in all beds

Main/Supplementary count 15/8/70
Species JL
Identity No. 62 (413)
Age 1u1 Section No. 2
Area of break 950 sq yds.

SAMPLE COUNTS (all living plants)

| | | | | | | | | | | | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 25 | 23 | 23 | 33 | 24 | 18 | 17 | 23 | | | 249 |
| 2 | 20 | 25 | 22 | 22 | 28 | 20 | 24 | 25 | | | 244 |
| 3 | 22 | 27 | 23 | 30 | 21 | 31 | 22 | 29 | | | 249 |
| 4 | 31 | 28 | 27 | 27 | 22 | 22 | 26 | 31 | | | 251 |
| 5 | 21 | 36 | 29 | 28 | 25 | 28 | 33 | 15 | | | 240 |
| 6 | 28 | 19 | 18 | 26 | 26 | 25 | 36 | 20 | | | 252 |
| 7 | 17 | 20 | 28 | 25 | 24 | 26 | 30 | 18 | | | 249 |
| 8 | 28 | 24 | 25 | 22 | 23 | 29 | 12 | 32 | | | 253 |
| 9 | 34 | 16 | 24 | 21 | 20 | 26 | 25 | 32 | | | |
| 10 | 31 | 26 | 30 | 17 | 27 | 27 | 24 | 28 | | | |
| | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | |
| 1 | | | | | | | | | | | |
| 2 | | | | | | | | | | | |
| 3 | | | | | | | | | | | |
| 4 | | | | | | | | | | | |
| 5 | | | | | | | | | | | |
| 6 | | | | | | | | | | | |
| 7 | | | | | | | | | | | |
| 8 | | | | | | | | | | | |
| 9 | | | | | | | | | | | |
| 10 | | | | | | | | | | | |
| | 110 | 120 | 130 | 140 | 150 | 160 | 170 | 180 | 190 | 200 | |

Revised Total Count (2) Total Count (1) 1987

EXAMPLE 2
Seedbed count where the first count was adequate. Height was measured at the time of stocktaking.
Beds laid out and assessed in metric units, are dealt with in exactly the same way as shown above.

*Table 37—continued.*

## EXAMPLE 3

### TRANSPLANT LINE STOCKTAKING

| | CALCULATIONS (1) | CALCULATIONS (2) | HEIGHT AND USABILITY CLASSIFICATION Height Class | (At end of season – 16/10) Tally | No. of plants in Class |
|---|---|---|---|---|---|
| C | 589 | | | | |
| N | 30 | | 6 | 卌, I | 6 |
| A | 19·6 | | 7 | 卌, II | 7 |
| L | | | 8 | IIII | 4 |
| L | | | 9 | 卌, 卌, III | 13 |
| L | 7620 | | 10 | 卌, 卌, 卌, II | 17 |
| T | 149 | | 11 | 卌, 卌, 卌, 卌, 卌, II | 27 |
| O | 180 | | 12 | 卌, 卌, 卌, 卌, 卌, 卌, III | 33 |
| AS% | 82·8 | | 13 | 卌, 卌, 卌, II | 17 |
| F | 13·7 | | 14 | 卌, 卌, 卌, 卌 | 20 |
| n | 0 | | 15+ | 卌, 卌, 卌 | 15 |
| V | 0 | | | | 159 |
| R | | | Unusables | 卌, 卌, 卌, 卌, I | 21 |
| N/S | | | | | |
| R-N | | | Total plants measured (t) | | 180 |

| | USABLES | |
|---|---|---|
| S | 6-12 | 8-14 |
| t | | 180 |
| u | | 159 |
| P | ·85 | ·884 |
| Use | 127 | 131 |

| SUMMARY OF STOCKS | | | | | |
|---|---|---|---|---|---|
| Total Stock (T) | SO | USE F | | USE RLO | |
| thous | thous | thous | size | thous | size |
| 149 | | 127 | 6-12 | (August guess) | |
| 149 | | 131 | 8-14 | (End of Season) | |

Some Neomyzaphis damage - not serious

$\frac{\text{Lines}}{\text{Beds}}$ : Average length 100 yds No. 12+

Total length of beds 1270 yds

Total length of lines 7620 yds

Preliminary estimate of survival 80 %

No. of samples 30

Distance between samples 20 yds/lines in 6 (All) beds

Main/~~Supplementary~~ count 14/8/70

Species SS

Identity No. 61 (7111)

Age 2+1 Section No. 46

Area of break 1750 sq yds

SAMPLE COUNTS (all living plants)

| | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 20 | 22 | 24 | | | | | | | | 194 |
| 2 | 23 | 21 | 21 | | | | | | | | 198 |
| 3 | 18 | 17 | 15 | | | | | | | | 197 |
| 4 | 24 | 15 | 14 | | | | | | | | |
| 5 | 19 | 14 | 17 | | | | | | | | |
| 6 | 20 | 19 | 18 | | | | | | | | |
| 7 | 17 | 25 | 20 | | | | | | | | |
| 8 | 18 | 24 | 22 | | | | | | | | |
| 9 | 14 | 23 | 24 | | | | | | | | |
| 10 | 21 | 18 | 22 | | | | | | | | |

| | 110 | 120 | 130 | 140 | 150 | 160 | 170 | 180 | 190 | 200 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | |
| 2 | | | | | | | | | | | |
| 3 | | | | | | | | | | | |
| 4 | | | | | | | | | | | |
| 5 | | | | | | | | | | | |
| 6 | | | | | | | | | | | |
| 7 | | | | | | | | | | | |
| 8 | | | | | | | | | | | |
| 9 | | | | | | | | | | | |
| 10 | | | | | | | | | | | |

Revised Total Count (2) 

Total Count (1) 589

EXAMPLE 3
Transplant count where the first count was adequate. An estimate made in August was corrected by an end-of-season height measurement.

*Table 37—continued.*

# EXAMPLE 4

## TRANSPLANT LINE STOCKTAKING

| | CALCULATIONS (1) | CALCULATIONS (2) |
|---|---|---|
| C | 1101 | 2848 |
| N | 30 | 80 |
| A | 36·7 | 35·6 |
| L | 2800 | |
| L | | |
| L | | |
| T | 103 | 100 |
| O | 140 | |
| AS% | 74 | 71 |
| F | 25·7 | |
| n | 8 | |
| V | ·267 | |
| R | 80 | |
| N/5 | 6 | |
| R·N | 50 | |

**HEIGHT AND USABILITY CLASSIFICATION**

| Height Class | Tally | No. of plants in Class |
|---|---|---|
| 3″+ | 卌,卌,卌,卌,卌,卌,卌,卌,卌,卌, 卌,卌,卌,卌,卌,卌,卌,卌,卌,卌, 卌,卌,卌,卌,卌,卌,卌,卌, II | 142 |
| Unusables | 卌,卌,卌,卌,卌,卌,卌, III | 38 |
| | Total plants measured (1) | 180 |

| USABLES | |
|---|---|
| S | 3-7 |
| t | 180 |
| u | 142 |
| P | ·788 |
| Use | 79 |

**SUMMARY OF STOCKS**

| Total Stock (T) | SO | USE F | | USE RLO | |
|---|---|---|---|---|---|
| thous | thous | thous | size | thous | size |
| 100 | | 79 | 3-7 | | |

Lines/Beds: Average length 80 yds No. 7+
Total length of beds 620 yds
Total length of lines ... yds
Preliminary estimate of survival 75 %
No. of samples 30 (+50)
Distance between samples 15 (12) yds yds/lines in 6 beds

Main/~~Supplementary~~ count 14/8/70
Species CP
Identity No. 62 (4253)
Age 1+1 Section No. 19
Area of break 1610 sq yds

**SAMPLE COUNTS (all living plants)**

| | | | | | | | | | | | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 38 | 41 | 49 | 42 | 38 | 31 | 27 | 32 | | | 358 |
| 2 | 25 | 45 | 42 | 39 | 44 | 35 | 29 | 20 | | | 375 |
| 3 | 19 | 50 | 44 | 32 | 49 | 28 | 31 | 26 | | | 368 |
| 4 | 49 | 47 | 24 | 41 | 50 | 39 | 43 | 28 | | | 327 |
| 5 | 44 | 40 | 39 | 30 | 46 | 43 | 47 | 24 | | | 406 |
| 6 | 50 | 39 | 25 | 28 | 41 | 37 | 28 | 31 | | | 351 |
| 7 | 46 | 29 | 38 | 25 | 40 | 36 | 25 | 37 | | | 345 |
| 8 | 27 | 24 | 49 | 22 | 35 | 48 | 38 | 39 | | | 318 |
| 9 | 22 | 23 | 21 | 33 | 34 | 30 | 50 | 43 | | | |
| 10 | 38 | 37 | 37 | 35 | 29 | 24 | 27 | 38 | | | |
| | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | |
| 1 | | | | | | | | | | | |
| 2 | | | | | | | | | | | |
| 3 | | | | | | | | | | | |
| 4 | | | | | | | | | | | |
| 5 | | | | | | | | | | | |
| 6 | | | | | | | | | | | |
| 7 | | | | | | | | | | | |
| 8 | | | | | | | | | | | |
| 9 | | | | | | | | | | | |
| 10 | | | | | | | | | | | |
| | 110 | 120 | 130 | 140 | 150 | 160 | 170 | 180 | 190 | 200 | |

Revised Total Count (2) 2848 Total Count (1) 1101

EXAMPLE 4.
Transplant count where the first count based on 30 samples revealed that the break was not very uniform so that 50 more samples had to be counted. Heights were measured only at the first count (6 heights on each of 30 samples).

*Table 37—continued.*

# EXAMPLE 5

## TRANSPLANT LINE STOCKTAKING

Lines/Beds : Average length 80 yds No. 65

Total length of beds 5200 yds

Total length of lines 26,000 yds

Preliminary estimate of survival 95 %

No. of samples 30

Distance between samples 16 yds lines in 6 beds

Main/~~Supplementary~~ count 15/8/70

Species SP

Identity No. 63 (411)

Age 1+1 Section No. 39

Area of break 5720 sq yds

| | CALCULATIONS (1) | CALCULATIONS (2) |
|---|---|---|
| C | 684 | |
| N | 30 | |
| A | 22·8 | |
| L | | |
| L | | |
| L | 26,000 | |
| T | 592 | |
| O | 624 | |
| AS% | 95 | |
| F | 15·9 | |
| n | 0 | |
| V | 0 | |
| R | — | |
| N/S | — | |
| R-N | — | |
| | USABLES | |
| S | 4-8 | |
| t | | |
| u | | |
| P | 98 | |
| Use | 580 | |

| HEIGHT AND USABILITY CLASSIFICATION | | |
|---|---|---|
| Height Class | Tally | No. of plants in Class |
| | | |
| Unusables | | |
| | Total plants measured (t) | |

| SUMMARY OF STOCKS | | | | | |
|---|---|---|---|---|---|
| Total Stock (T) | SO | USE | | | |
| | | F | | RLO | |
| thous | thous | thous | size | thous | size |
| 592 | | | | 580 | 4-8 |

| SAMPLE COUNTS (all living plants) | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 25 | 24 | 23 | | | | | | | | 221 |
| 2 | 20 | 24 | 23 | | | | | | | | 234 |
| 3 | 18 | 23 | 22 | | | | | | | | 229 |
| 4 | 23 | 25 | 21 | | | | | | | | |
| 5 | 24 | 23 | 22 | | | | | | | | |
| 6 | 24 | 24 | 24 | | | | | | | | |
| 7 | 22 | 23 | 24 | | | | | | | | |
| 8 | 20 | 23 | 23 | | | | | | | | |
| 9 | 21 | 21 | 25 | | | | | | | | |
| 10 | 24 | 24 | 22 | | | | | | | | |

| | 110 | 120 | 130 | 140 | 150 | 160 | 170 | 180 | 190 | 200 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | |
| 2 | | | | | | | | | | | |
| 3 | | | | | | | | | | | |
| 4 | | | | | | | | | | | |
| 5 | | | | | | | | | | | |
| 6 | | | | | | | | | | | |
| 7 | | | | | | | | | | | |
| 8 | | | | | | | | | | | |
| 9 | | | | | | | | | | | |
| 10 | | | | | | | | | | | |

Revised Total Count (2) 

Total Count (1) 684

EXAMPLE 5.
Transplant count where the first count was adequate, and where practically all plants were usable and of the same grade so that no height measurement was necessary.

## Appendix II

### Addresses of the Main Offices of the Forestry Commission

**Headquarters:**

FORESTRY COMMISSION, 25 SAVILE ROW, LONDON W1X 2AY. (01-734 0221).

**Conservators of Forests:**

### England

NORTH WEST

Forestry Commission, Dee Hills Park, Chester.
(0244 24006)

Cumberland, Westmorland, Lancashire, part West Riding of Yorkshire (Lune and Ribble Valleys), Cheshire, Shropshire, Staffordshire, Warwickshire, Leicestershire, Nottinghamshire and Derbyshire.

NORTH EAST

Forestry Commission, Briar House,
Fulford Road, York, YO1 4DB.
(0904 24684)

Northumberland, Durham, Yorkshire (except that part of West Riding in Lune and Ribble Valleys).

EAST

Forestry Commission, Block D, Government
Buildings, Brooklands Avenue, Cambridge.
(0223 54495)

Lincoln, Rutland, Norfolk, Cambridge, Northamptonshire, Bedfordshire, Oxfordshire, Buckinghamshire, Hertfordshire, Essex, Suffolk and Huntingdonshire.

NEW FOREST AND SOUTH EAST

Forestry Commission, The Queen's House,
Lyndhurst, Hants. SO4 7NH.
(0421-28 2801)

Berkshire, London, Middlesex, Kent, Sussex, Surrey, Hampshire, Isle of Wight and part Dorset (east of Salisbury-Blandford-Poole road).

SOUTH WEST AND DEAN FOREST

Forestry Commission,
Flowers Hill, Brislington, Bristol, 4.
(0272 78311)

Herefordshire, Gloucestershire, Wiltshire, Dorset (west of Salisbury-Blandford-Poole road), Worcestershire, Somerset, Devon and Cornwall.

### Scotland

NORTH

Forestry Commission, 60 Church Street,
Inverness.
(0463 32811)

Caithness, Sutherland, Ross and Cromarty, Inverness, part Argyll (Mull and areas west of Loch Linnhe), Nairn (except north-east corner), Moray (southern areas only), Orkney, Shetland.

EAST

Forestry Commission, 6 Queen's Gate,
Aberdeen, AB9 2NQ.
(0224 33361)

Nairn (north-east corner only), Moray (except southern areas) Banff, Aberdeen, Kincardine, Angus, Kinross, Fife (except south-west corner), part Perth (areas north and east of Crieff).

SOUTH

Forestry Commission, Greystone Park,
55/57 Moffat Road, Dumfries.
(0387 2425)

Midlothian, East Lothian, Berwick, Roxburgh, Selkirk, Peebles, Dumfries, Kirkcudbright, Wigtown, part Ayr (south of Kilmarnock), part Lanarkshire (south-east of Lanark).

WEST

Forestry Commission, 20 Renfrew Street,
Glasgow, C.2.
(041-332 7261)

Argyll (except Mull and areas west of Loch Linnhe), part Perth (areas west of Crieff), Stirling, Dunbarton, Renfrew, Clackmannan, part Fife (south-west corner only), part Ayr (north of Kilmarnock), part Lanarkshire (north-west of Lanark), West Lothian, Bute.

### Wales

NORTH

| | |
|---|---|
| Forestry Commission, Victoria House, Victoria Terrace, Aberystwyth. (0970 2367) | Anglesey, Caernarvon, Denbigh, Flint, Merioneth, Montgomery, Radnor, Cardigan (except south-west and south-east). |

SOUTH

| | |
|---|---|
| Forestry Commission, Churchill House, Churchill Way, Cardiff. (0222 40661) | Pembroke, Carmarthen, Brecknock, Glamorgan, Monmouth, south-western and south-eastern parts of Cardigan. |

**Director, Research:**

Forest Research Station, Alice Holt Lodge, Wrecclesham, Farnham, Surrey. (0420-4 2255).

Northern Research Station, Forestry Commission, Roslin, Midlothian, Scotland. (031-445 2176).

## APPENDIX III

### LIST OF LABORATORIES ABLE TO UNDERTAKE SOIL ANALYSES

**1. England and Wales**

*Forestry Commission:* Soils Section, Forest Research Station, Alice Holt Lodge, Wrecclesham, Farnham, Surrey.

(N.B. The laboratory here is not large enough to be able to undertake a large number of routine analyses. However, investigations requiring soil analysis are periodically undertaken).

*Agricultural Development Advisory Service*, Soils should be sent to the nearest A.D.A.S. laboratory after consultation with the soils chemist.

Regional Soil Scientist, A.D.A.S., Government Buildings, Kenton Bar, Newcastle-upon-Tyne (Northumberland, Durham, Cumberland, Westmorland and the North Riding of Yorkshire).

Regional Soil Scientist, A.D.A.S., Block 2, Government Buildings, Lawnswood, Leeds, 16 (East & West Riding of Yorkshire and Lancashire).

Regional Soil Scientist, A.D.A.S., Shardlow Hall, Shardlow, Derby (Derbyshire, Leicestershire, Lincolnshire—Kesteven and Lindsey, Northamptonshire, Nottinghamshire and Rutland).

Regional Soil Scientist, A.D.A.S., "Woodthorne", Wergs Road, Tettenhall, Wolverhampton, Staffs. (Cheshire, Shropshire, Staffordshire, Worcestershire, Warwickshire and Herefordshire).

Regional Soil Scientist, A.D.A.S., Block C, Government Buildings, Brooklands Avenue, Cambridge (Bedfordshire, Huntingdonshire, Cambridgeshire, Essex, Hertfordshire, Norfolk, Suffolk and Lincolnshire—Holland).

Regional Soil Scientist, A.D.A.S., Government Buildings, Coley Park, Reading (Berkshire, Oxfordshire, Buckinghamshire, Hampshire and Isle of Wight).

Regional Soil Scientist, A.D.A.S., Olantigh Road, Wye, Ashford, Kent (Kent, East Sussex, Surrey and West Sussex).

Regional Soil Scientist, A.D.A.S., Block 3, Government Buildings, Burghill Road, Westbury-on-Trym, Bristol (Dorset, Gloucestershire, Somerset and Wiltshire).

Regional Soil Scientist, A.D.A.S., Bryn Adda, Penrhos Road, Bangor, Caernarvonshire (Caernarvonshire, Anglesey, Denbighshire and Flintshire).

Senior Soil Scientist, A.D.A.S., Trawscoed, Aberystwyth, Cardiganshire (Merionethshire, Cardiganshire, Carmarthenshire, Montgomeryshire and Pembrokeshire).

Senior Soil Scientist, A.D.A.S., 66 Tyglas Road, Llanishen, Cardiff (Breconshire, Radnorshire, Glamorganshire and Monmouthshire).

Senior Soil Scientist, A.D.A.S., Staplake Mount, Starcross, Exeter, Devonshire (Devonshire, Cornwall and Isles of Scilly).

*Note.* On 1st April 1971 what had until that date been the National Agricultural Advisory Service was merged with other sections of the Ministry of Agriculture, Fisheries and Food to become the Agricultural Development Advisory Service (A.D.A.S.).

**2. Scotland**

Forest Soils Section, Macaulay Institute for Soil Research, Aberdeen, Scotland.

## APPENDIX IV

### COMPARISON OF INORGANICS AND BULKY ORGANICS ON SEEDBEDS CROPPED ANNUALLY FOR THIRTEEN YEARS—BRAMSHILL HEATHLAND NURSERY


SUMMARY

There were small differences in height between seedlings grown on plots given either inorganics or organics annually. At the rates of nutrients applied, a combined regime gave most consistent height growth. The number of seedlings was reduced by 10 per cent by organics. Analyses of soils at the end of the period showed differences in residues attributable to treatment. Growth on organic residues in the last year of the experiment was relatively good. Residues from inorganics though measurable had little effect on growth.


### Introduction

Rayner (1944) had shown that seedlings could be raised on heathland soils with added bulky organics; she attributed this to the biological value of compost in stimulating mycorrhizas and discounted the effect of composts as a source of nutrients. Crowther challenged Rayner's explanation. Consequently, between 1945 and 1949 many experiments were undertaken in Forestry Commission nurseries to determine the role of organic matter in production of forest nursery stock. These experiments soon demonstrated firstly, that the effect of organics could be accounted for in terms of their nutrient content, and secondly that inorganics could be as effective as composts in ensuring vigorous growth of conifers. If composts and bulky organics were graded according to their content of nutrients, bracken-hopwaste compost was the best of those tested, providing N, P and K in reasonable proportion; straw-hopwaste compost was only a little lower in its content of K (Benzian, 1965; pages 97–130).

In 1949, four long term experiments were planned for English and Welsh nurseries comparing inorganics and compost (Ibid; pages 121–122). The experiments were designed to be large enough for the techniques of large-scale nursery management to be used. However, many practical difficulties were encountered in the first two years and only at Bramshill nursery (near Hartley Wintney, Hants.), was the experiment persisted with.

In Scotland at Teindland nursery, Morayshire, a parallel experiment was started and has run for 17 years. Brief progress notes on this latter experiment are given in chapters entitled, 'Nursery Investigations' in the annual *Forestry Commission Reports on Forest Research.*

### Site

The site at Bramshill was at Elvetham Nursery, near the top of a gentle slope. (Grid ref. SU 796555). The soil (Avery, 1965) is sandy in texture and the profile before cultivation was a humus-iron podzol, in parts well drained and in parts imperfectly drained. Elevation—230 ft/*70 m* O.D.

### Treatments

Four treatments were applied annually; these were inorganics only; bulky organics only; both; neither. There were four replicates. Treatments were applied each year from 1950 to 1961 to plots consisting of 4 adjacent seedbeds each 24 feet/*7.3 m* long. Rates of nutrients applied are given in Table 38.

TABLE 38

MATERIAL APPLIED ANNUALLY BETWEEN 1950 AND 1962 IN COMPARISON OF INORGANICS AND ORGANICS: BRAMSHILL FOREST

| Material | Period | Mean Nutrient Rate: lb per acre** | | | |
|---|---|---|---|---|---|
| | | N | P | K | Mg |
| | *Organic* regimes* | | | | |
| Straw-hopwaste compost | 1950–1953 | 360 | 80 | 70 | 35 |
| Raw hopwaste | 1954, 1957 | 300 | 65 | 13 | 25 |
| Bracken-hopwaste compost | 1955–1962 except 1957 | 320 | 65 | 140 | 25 |
| | *Inorganic regimes* | | | | |
| Potassic super-phosphate + Nitrochalk | 1950–1958 | 90 | 47 | 90 | 0 |
| As above + Epsom salts + additional super-phosphate | 1959–1962 | 90 | 94 | 90 | 32 |

*Nutrient content of organic regimes is based on conservative figures from within the lower part of the range of values shown in Tables 80 and 81, Bulletin 37 (Benzian, 1965). Bulky organics were stored out of doors not under cover, and therefore were subject to some loss by leaching.

***To convert lb per acre to kg per hectare, multiply the figures in the table by 1.1.*

In 1962, each plot was split into four, each part receiving one of the four treatments. (In effect, one quarter of each plot was kept under its original treatment, one quarter was cropped without any further additions; thus providing some estimate of the effect of residues, while the remaining quarters indicated the effect of residues in combination with one year of other regimes).

All beds were cropped annually with Sitka spruce seedlings, being prepared and maintained as far as possible following standard procedures of cultivation, weed control etc. Unfortunately, the early batches of straw-hopwaste compost contained many weed seeds and the site became weedy much sooner than was desirable or had been expected.

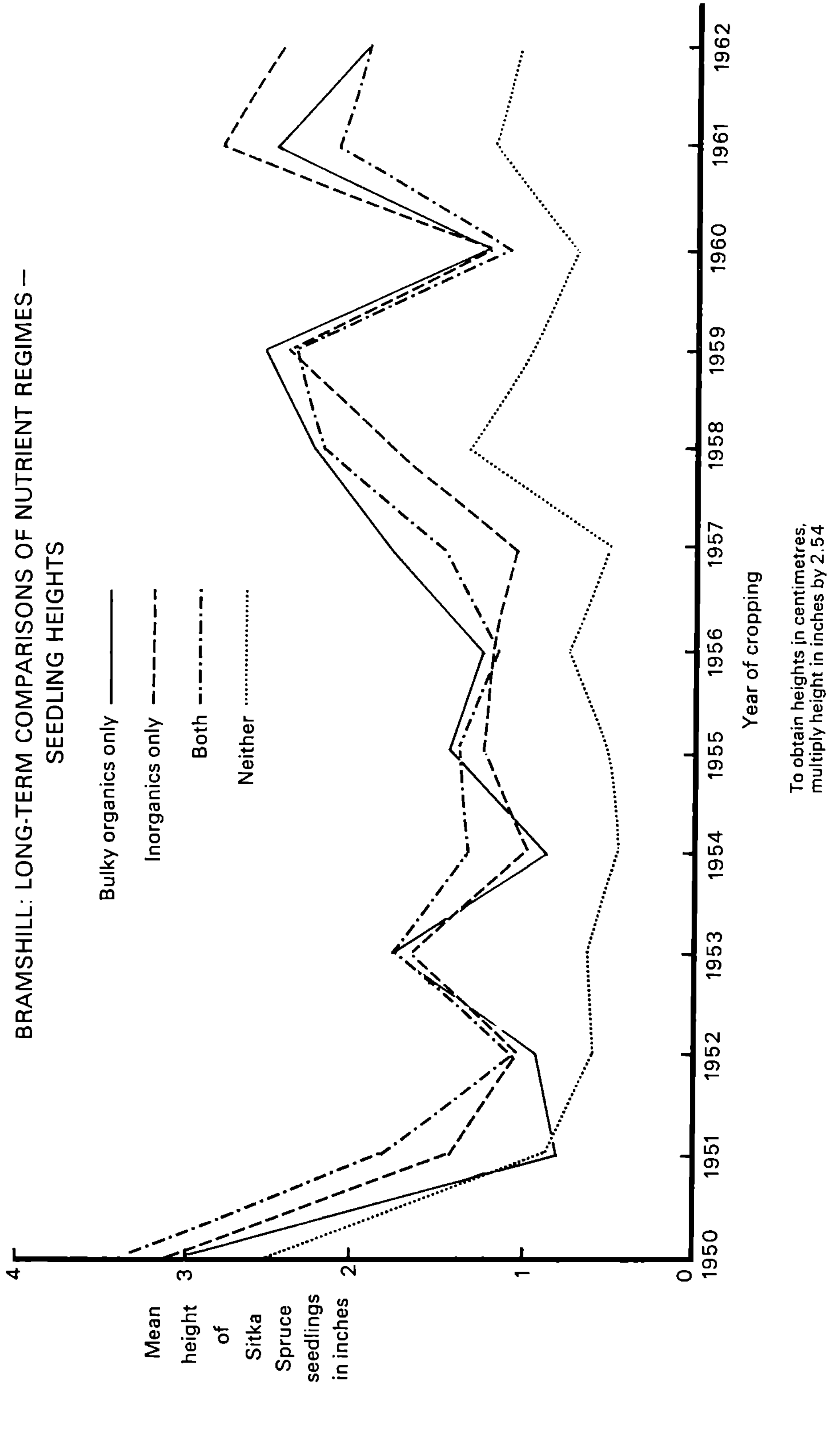
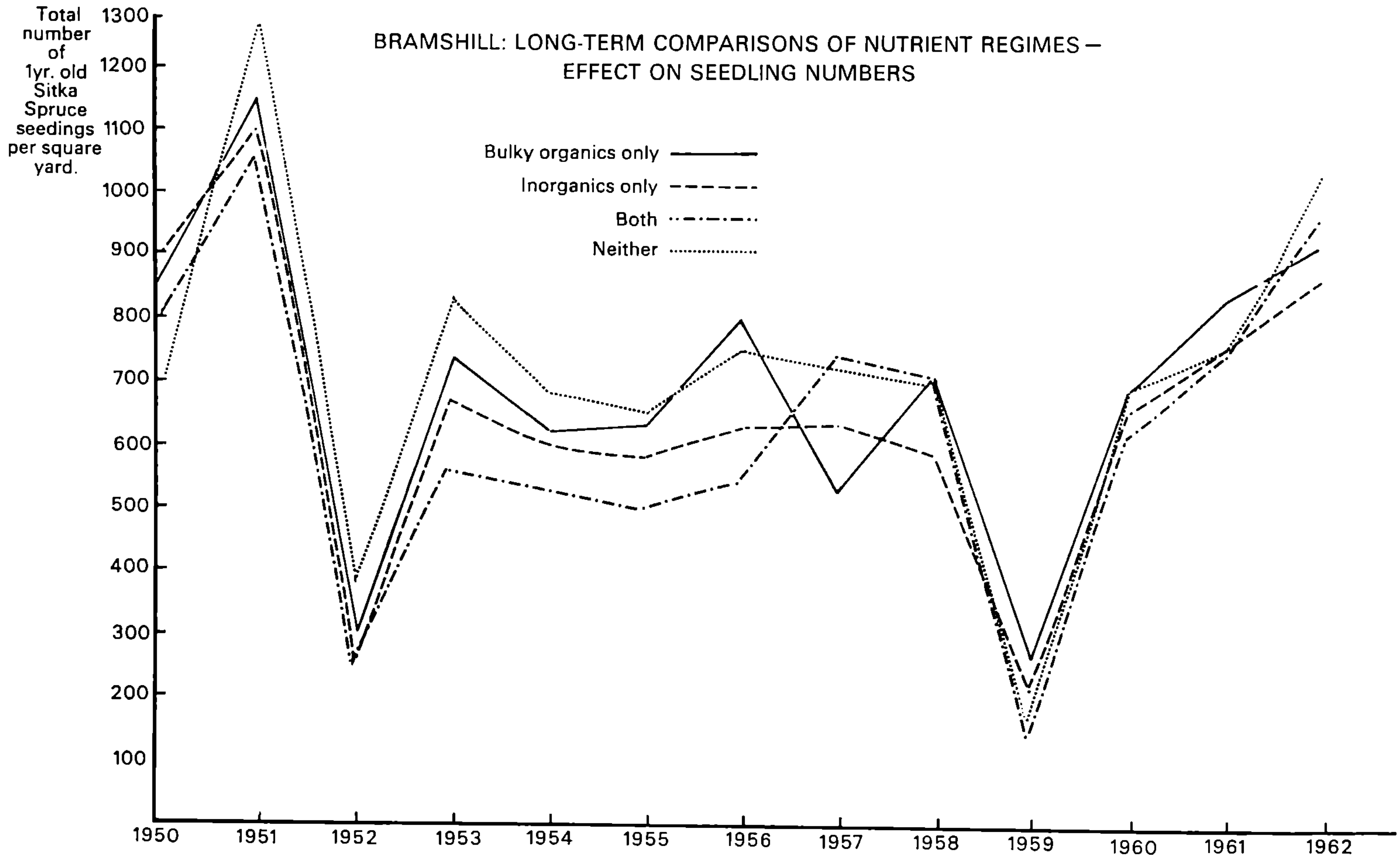



**Fig. 10.** Bramshill Nursery. Height of 1 year-old seedlings on seedbeds cropped annually and given inorganics or bulky organics.




To obtain numbers per square metre,
multiply numbers per square yard by 1.2

Fig. 11. Bramshill Nursery. Number of 1 year-old seedlings on seedbeds cropped annually and given inorganics or bulky organics.

TABLE 39

SEEDLING NUMBERS AND HEIGHTS OF SITKA SEEDLINGS
MEAN OF ANNUAL CROPS—BRAMSHILL

| Treatment | Number of seedlings | | | | Mean Height | | | |
|---|---|---|---|---|---|---|---|---|
| | 1950–55 | | 1956–62 | | 1950–55 | | 1956–62 | |
| | *per sq yd* | *per sq m* | *per sq yd* | *per sq m* | *inches* | *cm* | *inches* | *cm* |
| Inorganics | 729 | *872* | 745 | *891* | 1.67 | *4.2* | 1.62 | *4.0* |
| Bulky organics | 629 | *752* | 668 | *799* | 1.46 | *3.7* | 1.88 | *4.7* |
| Both | 695 | *831* | 650 | *777* | 1.68 | *4.2* | 1.91 | *4.8* |
| Neither | 764 | *915* | 723 | *865* | 0.94 | *2.4* | 0.90 | *2.2* |

TABLE 40

HEIGHT IN INCHES OF 1 + 0 SITKA SPRUCE SEEDLINGS IN 1962—
13TH YEAR OF CONTINUOUS CROPPING
BRAMSHILL***

| Treatment in 1st 12 years | Treatment in 13th year | | | | | Mean* |
|---|---|---|---|---|---|---|
| | Same treatment as in preceding years | Inorganics | Bulky Organics | Both | Neither | |
| Inorganics | 1.89 | 1.89 | 1.66 | 2.06 | 1.38 | 1.75 |
| Bulky organics | 1.88 | 2.48 | 1.88 | 2.72 | 1.50 | 2.15 |
| Both | 2.41 | 2.43 | 2.14 | 2.41 | 1.96 | 2.24 |
| Neither | 1.04 | 1.95 | 1.64 | 2.18 | 1.04 | 1.70 |
| Mean ** | | 2.19 | 1.83 | 2.34 | 1.47 | |

* i.e. overall effect of previous 12 years treatments on 13th years growth, (Standard error: 0.16).
**i.e. overall effect of treatment in 13th year (Standard error: 0.06).
***To convert to height in cm, multiply figures in table by 2.54.

TABLE 41

SOIL AND PLANT ANALYSES FROM PLOTS UNDER SAME REGIME FOR 13 YEARS: SAMPLED IN NOVEMBER, 1962

| Treatment (1950–1962) | Soil Analyses | | | | | | | | Plant Analyses | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | pH | Organic Matter % | N % | Org M /N ratio | P Total % | P Readily Soluble mg/100gr | K me/ 100g | Mg | N | P | K | Ca | Mg |
| | | | | | | | | | % in shoots | | | | |
| Inorganics | 5.2 | 3.1 | 0.055 | 56 | 0.024 | 3.8 | 0.039 | 0.16 | 1.5 | 0.28 | 0.79 | 0.43 | 0.086 |
| Bulky organics | 5.2 | 4.2 | 0.092 | 46 | 0.021 | 1.2 | 0.031 | 0.18 | 1.7 | 0.29 | 0.44 | 0.50 | 0.116 |
| Both | 5.0 | 4.0 | 0.114 | 35 | 0.026 | 3.8 | 0.046 | 0.26 | 1.6 | 0.28 | 0.79 | 0.44 | 0.079 |
| Neither | 5.3 | 3.2 | 0.073 | 44 | 0.018 | 0.6 | 0.025 | 0.17 | 1.6 | 0.27 | 0.44 | 0.52 | 0.062 |
| Standard error: | | 0.15 | 0.008 | | | 0.54 | 0.002 | 0.032 | 0.15 | 0.013 | 0.07 | 0.03 | 0.009 |

*Note:* P was extracted from soil with 2½% acetic acid; exchangeable K by leaching with neutral N ammonium acetate.

## Results

### The Effect of 13 Years Continuous Cropping

The yield and growth of seedlings in each year are given in Figures 10 and 11. From these, it will be seen that the numbers of seedlings was fairly steady except in the warm summers of 1952 and 1959 when they dropped sharply. Heights have varied rather more. The seedlings on untreated plots were consistently small but the height of seedlings raised on the other regimes differed from each other to a smaller extent than from the controls in most years. The plots given organics on average have yielded 10 per cent fewer seedlings than those on inorganics. Table 39 summarises the data in Figures 10 and

11, giving mean annual heights and yields for periods of six and seven years respectively.

There is little difference between the number of seedlings in the two periods; in both, numbers on plots including organics are a little less than on those without. There are also small differences in height between seedlings raised on organics and inorganics. In the first period, seedlings on inorganics are slightly taller than those on organics alone; in the second period, this situation was reversed. While this might be attributable to the use of organics *per se*, at the same time the organics in the first period were given mainly as straw-hopwaste compost while in the later period, it was mainly bracken-hopwaste compost, which is better provided with K. For consistency in sustaining good growth, the combined treatment has a small advantage.

**1962 Results—Evaluation of Residues**

The heights of Sitka spruce seedlings in 1962 are summarised in Table 40; the results of analysis of samples of soil and of plant foliage taken in Autumn 1962 are given in Tables 41 and 42.

Table 40, Column 2 shows that, of the continuing treatments, there was little to choose in the 13th year between inorganics and bulky organics; at the rates and times applied, the two together were better than either separately. Columns 3–6 of Table 40 show that better growth was obtained on plots given inorganics in 1962 than on those given bulky organics in 1962, but that for all 1962 treatments, the sub-plots which had in the previous 12 years been given bulky organics, yielded bigger seedlings than those fertilised continuously with inorganics.

Table 41 shows that plots given inorganics have over three times as much readily soluble P in the soil as on plots given organics or nothing. Differences in the total P content in the soil and in P in the plants were very much less pronounced. There was however more exchangeable K in the soil on plots given inorganics—this is also reflected by the marked differences in K in the foliage which is very low in plants from the bulky organics plots.

Tables 40 and 41 show that both as regards residues of K in the soil and in the amount of K taken up by plants, there was a significant response not only to the previous treatments but also to the 1962 treatment. Plants were able to pick up as much K from inorganic residues as they did from currently applied inorganics.

Table 41 shows that plots given bulky organics had slightly more organic matter in the soil. While the differences were significant, they were not great when compared with the general level of variation of soil organic matter from place to place within an area. There was also more N in the soil on plots given organics; the organic matter/N ratio was highest on plots given inorganics and lowest on those given both inorganics and organics.

**Discussion and Conclusions**

The overall effect of residues on growth is summarised in the last column of Table 40. Better growth was obtained on residues from organic plots but there was little response to inorganic residues by themselves in spite of the measurable increases in soil P and K. Plants on plots treated for 12 years with both inorganic and organic residues but with no further addition at all in the 13th year, grew as well as those on ground given continuous inorganic or continuous organic manuring. The good growth of seedlings given inorganics only on plots with residues from organics should also be noted.

These results raise as many questions as they settle. For example, would results have differed materially if inorganics plots had been given more top dressings—for example with N or K? Results from the Teindland experiment indicate scope for such variations (Atterson, 1967: Aldhous, Atterson *et al.*, 1967). Has the variation in the form of organic matter invalidated any of the comparisons? Should attempts have been made to distinguish between forms of organic matter when considering the value of residues from organic treatments or is the C/N ratio more relevant? What relevance do these results have to modern nursery practice?

The problem in long-term experiments of what to do when a regime is clearly insufficient to supply plants' needs is impossible to solve without either losing continuity of treatment or producing plants that may be so inadequate as to throw in doubt the whole basis of the comparisons made. Benzian (1967) reports results from two very elaborate trials and over a twelve year period

TABLE 42

K RESIDUES IN SOILS FROM ALL PLOTS TREATED IN 1962

| Treatments 1950–1961 | 1962 Treatments Inorganics | Bulky Organics | Both | Neither | Mean |
|---|---|---|---|---|---|
| | *me/100 g of soil* | | | | |
| Inorganics | 0.039 | 0.035 | 0.045 | 0.031 | 0.037 |
| Bulky organics | 0.039 | 0.031 | 0.046 | 0.026 | 0.035 |
| Both | 0.055 | 0.039 | 0.047 | 0.041 | 0.045 |
| Neither | 0.031 | 0.029 | 0.037 | 0.025 | 0.031 |
| Mean | 0.041 | 0.033 | 0.044 | 0.031 | |

Standard Errors: Values in main part of table, 0.004; 1962 treatment means 0.002; 1950–61 treatment means, 0.003.

TABLE 43
PERCENTAGE OF K IN PLANT SHOOTS FROM PLOTS TREATED IN 1962

| Treatments 1950–1961 | 1962 Treatments Inorganics | Bulky Organics | Both | Neither | Mean |
|---|---|---|---|---|---|
| | % *in Shoots* | | | | |
| Inorganics | 0.79 | 0.74 | 1.01 | 0.64 | 0.80 |
| Organics | 0.77 | 0.44 | 0.85 | 0.32 | 0.60 |
| Both | 0.86 | 0.68 | 0.79 | 0.72 | 0.76 |
| Neither | 0.77 | 0.58 | 0.81 | 0.44 | 0.65 |
| Mean | 0.80 | 0.61 | 0.87 | 0.53 | |

Standard Errors: Values in main part of table, 0.070; 1962 treatment means, 0.035; previous treatment means, 0.058.

made several changes to the nutrient regimes being compared; even so, neither regime was completely adequate for plants. In Scotland, at Teindland it was possible to introduce experimental comparisons into the large plots and so get an idea of the consequences of changes. (Atterson, 1967; Aldhous, Atterson *et al.*, 1967).

The only result regularly reported from experiments comparing inorganics and bulky organics is that on average, organic matter applied to seedbeds reduces numbers of seedlings from sowings that year. This conclusion is supported by results of this experiment. The reduction in numbers may be due to increased fungal action (Bloomberg, 1963; Schönhar, 1968; Redfern, 1969), possibly benefitting from the large amounts of added N or it may be due to interference to the capillary rise of water in or water storage by sandy soils where good consolidation is vital to satisfactory germination of seedlings. In this context, Benzian (1967) reported difficulty in consolidating seedbeds at Wareham when the quantity of added organic matter was increased to 30 tons per acre.

In the experiment reported here, growth of seedlings cannot be said to be clearly best on any one regime. At the rates of application chosen, organics and inorganics together or either used where there are organic residues, have done well. Benzian (1967) found that transplants grew taller on organics on light soils than on inorganics. It therefore seems logical on sands and very light loams—which form a large proportion of forest nursery soils—to recommend the application of bulky organics to transplants and to grow seedlings on inorganics plus any residues from the manuring of transplants. Such a regime should get the benefit of the organic residues but may avoid the losses of seedlings due to the use of bulky organics on seedbeds.

The results at Bramshill in the final year when plots were split and some treatments switched round has no parallel in other British forest nursery experiments. It is possible that the benefit to plants of organic residues could be accounted for by the N residues and the lower organic matter/nitrogen ratio. Certainly the differences in organic matter were small and can only be important if they concealed differences in the type of organic matter present. The amounts of K in both plants and the soil at the end of 1962 were also strongly correlated to the growth of plants. Perhaps the principal conclusion from the experiment is that once again, a combination of N, P and K is necessary for plant growth and that in this instance, both residues and those nutrients supplied in the year of cropping played an important part in providing the supply of N, P and K to ensure vigorous growth.

## REFERENCES

ALDHOUS, J. R., ATTERSON, J. *et al.* 1967. Long-term Maintenance of Fertility. *Rep. Forest Res.*, Lond. 1967. 36–38.

ATTERSON, J. 1967. Long-term Fertility trials in Scotland *Rep. Forest Res. Lond.* 1966, 21–22.

AVERY, B. W., 1965. Soils in Chapter 2, *Nutrition Problems in Forest Nurseries.* Bull. For. Comm. Lond. 37. 14–18.

BENZIAN, B., 1965. *Nutrition Problems in Forest Nurseries.* Bull. For. Commn. Lond. 37.

BENZIAN, B. 1966. Manuring young conifers: experiments in some English nurseries. *Proc. Fertil. Soc.* **94** 5–37.

BLOOMBERG, W. J. 1963. Use of organic residues in forest nurseries. Can. Dep. For., For. Ent. and Path. Branch Bi-month. Progr. Rept., **19** (6) 4.

RAYNER, M. C. and NEILSON-JONES, W. 1944. *Problems in Tree Nutrition.* Faber & Faber Ltd. London.

REDFERN, D. B. 1969. The effect of Organic Residues on Damping off. M/S in preparation—personal communication.

SCHÖNHAR, VON S. 1968. Untersuchungen über des vorkommen Nadelholzsaaten gefahrdender Keimlingspilze in Komposterden. *Allg. Forst und Jagdztg.*, **139** (10) 227–229.

## Appendix V

## Observations on the Response of Annual Meadow Grass, Poa Annua, and some other Common Weeds to Soil pH


SUMMARY

In two forest nurseries *Poa annua* reached an optimum development at pH 5.5, assessed both by fresh weight of weeds removed and weeding times. This weed was by far the most important present and was the only one for which any response curve to soil pH could confidently be drawn.


### Introduction

As part of the programme of investigations into nutritional problems in forest nurseries, experiments were laid down in which the pH of the soil was altered so that soils with a graduated sequence of pH values occurred in each experimental block. These experiments are fully described in Chapter 5 of Bulletin 37, *Experiments on Nutrition Problems in Forest Nurseries* (Benzian, 1965). There are two such "pH range" experiments, one at Wareham, Dorset, and one at Kennington, Oxford.

In the experiment at Wareham, it was noticed in July 1960 that parts of some beds were weedier than others and that this was related to experimental differences in the pH of the soil (Plate 17), the weedy patches being where the pH was somewhat higher than in the nursery as a whole.

The plot by plot pH values in the experiments at Wareham and at Kennington are given in Table 44. These values were obtained after mixing the soil with a 0.01 M solution of calcium chloride. As the data in the earlier part of this bulletin refer to pH values obtained by mixing soils with water, in Table 44 and all subsequent references in this paper, 0.5 has been added to each original mean plot value to give an estimate of the pH measured in water.

In addition to covering a range of pH values, plots are given nitrogen top-dressings using one of the three materials, ammonium sulphate, 'Nitro-chalk' and calcium nitrate. These have interacted with the pH of the soil so that plots given ammonium sulphate are more acid than those given 'Nitro-chalk' or calcium nitrate.

### Observations made

At Wareham, the time taken to weed the pH range experiment was assessed square yard by square yard. The results in relation to the pH of the soil are given in Figure 12.

Weeding times for the different nitrogen treatments are also shown on the figure. The weeds present at Wareham were almost exclusively of one species, Annual meadow grass (*Poa annua*); there were very small amounts of chickweed (*Stellaria media*) and groundsel (*Senecio vulgaris*) but not enough to influence weeding times. It will be seen from Figure 12 that, as assessed by weeding times, Annual meadow grass is highly responsive to soil pH and reaches its optimum at pH 5.5.

At Kennington, in 1962, more detailed analyses were made of the weeds present on the counterpart experiment. The time taken to weed was again assessed but in addition, the principal weeds present were weighed and the others recorded. Again the dominant weed was Annual meadow grass. There were also appreciable numbers of Hop trefoil (*Trifolium campestre*), knotgrass (*Polygonum aviculare*), chickweed (*Stellaria media*), sowthistle

TABLE 44

pH Values in Experiments Observed at Kennington and Wareham
(Mean of four replicates)
(Original value from measurement in Ca $Cl_2$ in roman type;
estimated corresponding value for measurement in water *in italics*)

| Form in which nitrogen topdressing is applied | Plot No. 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Kennington** | | | | | | | | | | | | | | | | |
| Ammonium sulphate | 3.8 | 3.8 | 3.8 | 3.8 | 3.9 | 3.9 | 3.9 | 3.9 | 3.9 | 3.9 | 4.0 | 4.1 | 4.4 | 5.0 | 6.5 | 6.9 |
| | *4.3* | *4.3* | *4.3* | *4.3* | *4.4* | *4.4* | *4.4* | *4.4* | *4.4* | *4.4* | *4.5* | *4.6* | *4.9* | *5.5* | *7.0* | *7.4* |
| 'Nitro-chalk' / Calcium nitrate | 4.0 | 4.0 | 4.0 | 4.0 | 4.2 | 4.2 | 4.3 | 4.3 | 4.3 | 4.4 | 4.6 | 5.0 | 5.4 | 6.0 | 6.8 | 7.3 |
| | *4.5* | *4.5* | *4.5* | *4.5* | *4.7* | *4.7* | *4.8* | *4.8* | *4.8* | *4.9* | *5.1* | *5.5* | *5.9* | *6.5* | *7.3* | *7.9* |
| **Wareham** | | | | | | | | | | | | | | | | |
| Ammonium sulphate | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 3.4 | 3.5 | 4.0 | 5.4 | 6.2 | Only 12 plots per replicate | | | |
| | *3.8* | *3.8* | *3.8* | *3.8* | *3.8* | *3.8* | *3.8* | *3.9* | *4.0* | *4.5* | *5.9* | *6.7* | | | | |
| 'Nitro-chalk' / Calcium nitrate | 3.8 | 3.8 | 3.9 | 4.0 | 4.0 | 4.0 | 4.1 | 4.3 | 4.8 | 5.5 | 6.4 | 6.6 | | | | |
| | *4.3* | *4.3* | *4.4* | *4.5* | *4.5* | *4.5* | *4.6* | *4.8* | *5.3* | *6.0* | *6.9* | *7.1* | | | | |

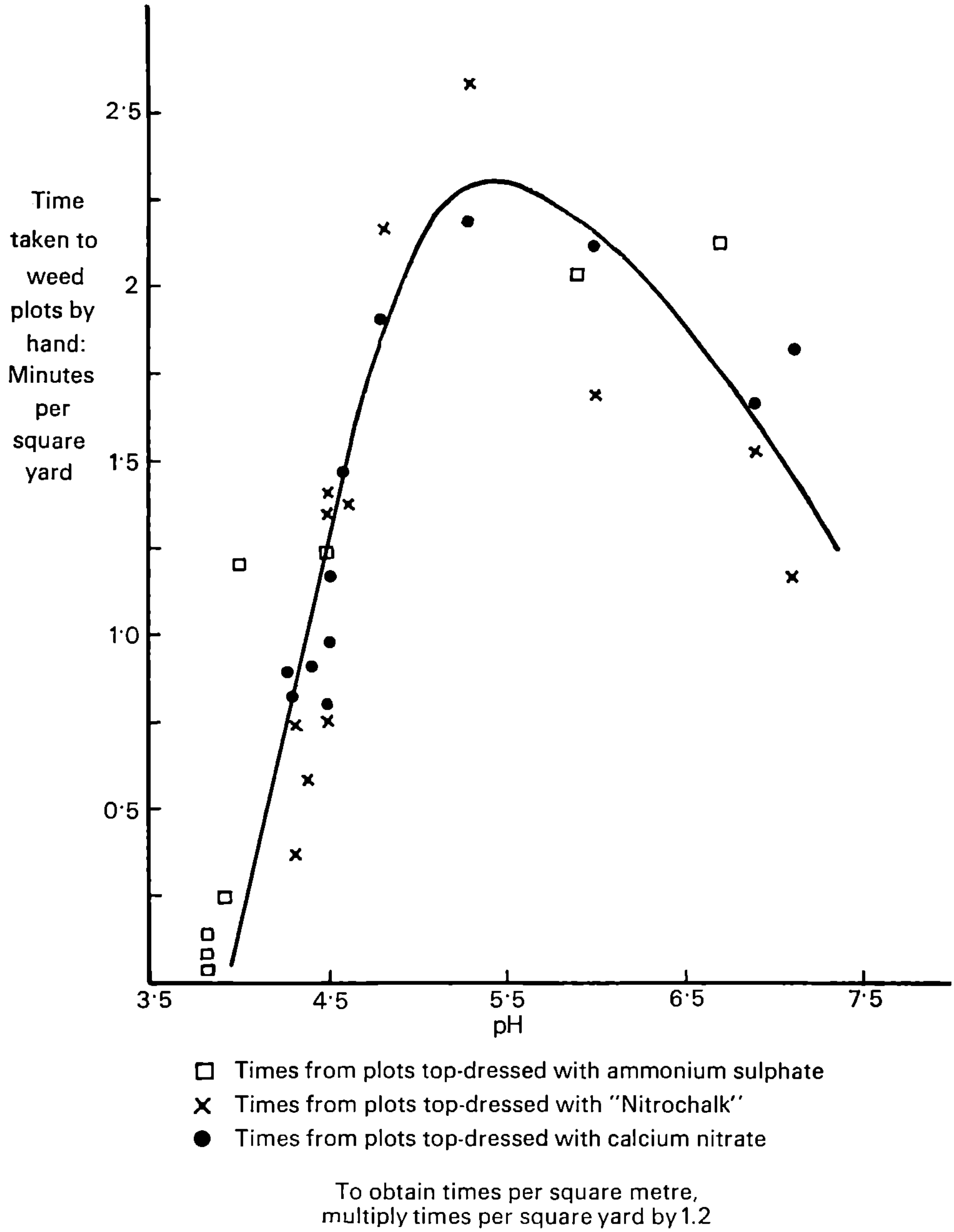
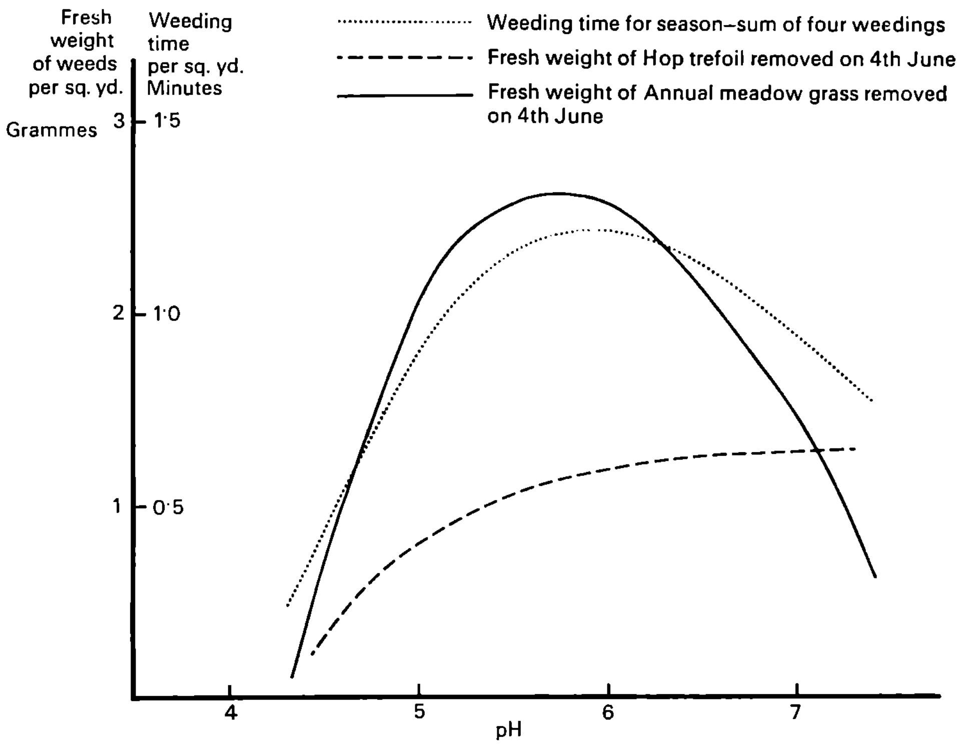



Fig. 12. Wareham Nursery. Timed weeding in relation to pH; dominant weed species—Annual meadow grass, *Poa annua*.

(*Sonchus oleraceus*), groundsel (*Senecio vulgaris*) and pearlwort (*Sagina procumbens*) and occasional fat hen (*Chenopodium album*), bindweed (*Convolvulus arvensis*), Herb robert (*Geranium robertianum*) and rush (*Juncus* sp.) Six other species occurred so infrequently as not to be worth listing.

Figure 13 shows the hand-weeding times in minutes per square yard from Kennington in 1962. The curve is similar to that at Wareham, and illustrates the dominating effect of Annual meadow grass. Most weeds were removed in the first weeding of the season, which took place on June 4 and 5. The other curves on Figure 13 show the fresh weights of Annual meadow grass and Hop trefoil then removed. Other weeds at this time contributed very little to the fresh weight of weeds removed. The shape of the curves for the weight of weeds removed differs appreciably, the maximum weight of Annual meadow grass being removed at pH 5.5, while the trefoil showed no sharp peaks.




Weeding time and weight of weeds in relation to pH
Kennington nursery 1962

To obtain times or weights per square metre, multiply corresponding value per square yard by 1.2

Fig. 13. Weed responses at Kennington Nursery.

Some responses of the other weeds present are shown in Tables 45 and 46. Table 45 shows the relative frequency of 'occasional' weeds on plots at different pHs. Frequency figures are derived from an assessment of presence or absence of a weed at the time of each of the four weedings. As there were four replicates, the maximum frequency possible was 16. Of these occasional weeds, knotgrass and groundsel appear to be independent of pH, but chickweed, sowthistle and pearlwort occur more frequently on soils with pH 5.0 and over.

Table 46 shows the number of plots on which weeds were observed at each of the four weedings during the 1962 season. There were in the experiment at Kennington, 192 plots under observation at each weeding. The table illustrates clear differences in patterns of emergence. The sustained period of germination of Hop trefoil is particularly clearly brought out.

TABLE 45

RELATIONSHIP BETWEEN pH AND THE FREQUENCY OF WEEDS OCCURING OCCASIONALLY IN pH RANGE EXPERIMENT

KENNINGTON NURSERY, 1962

| Weed Species | pH of Plot 4.3 | 4.4 | 4.5 | 4.6 | 4.7 | 4.8 | 4.9 | 5.1 | 5.5 | 5.9 | 6.5 | 7.0 | 7.3 | 7.4 | 7.5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean number of plots on which weeds were observed (Maximum possible—16) | | | | | | | | | | | | | | |
| Chickweed | 0 | 0.7 | 0.1 | 1 | 0.5 | 0.5 | 0.7 | 2 | 0.7 | 2 | 2 | 3 | 3 | 2 | 3 |
| Groundsel | 0 | 0.3 | 0.1 | 0 | 0.2 | 0.3 | 0 | 0 | 0.3 | 1 | 0.5 | 1 | 0 | 0 | 0.5 |
| Knotgrass | 1.2 | 0.8 | 1.2 | 2 | 0.5 | 0.2 | 1 | 0.5 | 1.3 | 1.5 | 1.5 | 2 | 1 | 1 | 1 |
| Pearlwort | 0 | 0 | 0.3 | 0 | 0.5 | 0.8 | 1.7 | 4 | 3.8 | 3 | 3 | 3 | 6 | 4 | 3.5 |
| Sowthistle | 0.2 | 0.3 | 0.4 | 0 | 0.2 | 0.3 | 1.3 | 2 | 0.3 | 1 | 2 | 1 | 1 | 2 | 1 |

TABLE 46

DATE OF WEEDING AND THE FREQUENCY OF WEEDS IN pH RANGE EXPERIMENT

KENNINGTON, 1962

| Weed Species | Date of Weeding June 4/5 | June 26 | July 30 | August 22 |
|---|---|---|---|---|
| Total number of plots on which weeds were observed (Maximum possible—192) | | | | |
| Annual meadow grass | 179 | 100 | 34 | 33 |
| Hop trefoil | 152 | 95 | 66 | 76 |
| Chickweed | 35 | 4 | 0 | 2 |
| Groundsel | 12 | 0 | 0 | 0 |
| Knotgrass | 43 | 5 | 0 | 0 |
| Pearlwort | 23 | 30 | 15 | 2 |
| Sowthistle | 26 | 1 | 0 | 2 |

**Discussion and Conclusions**

These results show that the pH most suited to Annual meadow grass is about 5.5. There is insufficient data to support any firm conclusion for other species, though several species appear more frequently on the plots with a higher pH. One feature of these observations is the relative infrequency of many of the common arable weeds on plots at higher pHs. Probably the answer lies partly in the fact that nursery managers attempt to keep the soil in forest nurseries at a pH of 5.0 or less—this is certainly so of the ground immediately adjoining these experiments, and partly in the high standard of husbandry in these nurseries which has ensured the absolute minimum of seeding. At Wareham, the ground was very acid *Calluna* heathland before it was taken in for forest nursery production and there is virtually no residual weed seed in the soil from preceding cropping. The section at Kennington was taken in from grassland in 1945; some weed seeds of arable farming may date from before this date. These factors together probably account for the low numbers of other weeds.

Annual meadow grass is able to set seed within four to six weeks of germination, and appears to have a relatively long period over which it can germinate. This and its relative tolerance of acid soils accounts for its prevalence in forest nurseries in Britain. Hop trefoil appears from Table 46 to be a problem at Kennington but it has not the ability to seed prolifically, nor to germinate speedily and therefore is much less of a weeding problem than is Annual meadow grass. Pearlwort though occurring on fewer plots in this experiment, is perhaps more of a threat than Hop trefoil on account of its prostrate habit and the relative difficulty of removing the whole plant when weeding.

## Appendix VI

## Trials of Formalin and Chloropicrin 1951—1956

SUMMARY

The trials described demonstrated that increases in the height of conifer seedlings can consistently be obtained on soils ranging in texture from light to moderately heavy loams following a formalin drench or injection of chloropicrin. Increases were less consistent on sandy or on heavy soils. Treatments in January or February gave better results than those in March or April.

The magnitude of the height increase following formalin drench or chloropicrin injection was sufficient to increase the proportion of usable seedlings by between 20 and 60 per cent in those nurseries where the average height of one-year seedlings in untreated beds was between 1 and 2 inches/2.5 *to* 5 *cm*.

Table 47

Sites of Nursery Trials with Formalin and Chloropicrin

| Name of Forest and Nursery | County | Soil Texture | pH of Soil | Age (in 1956) | Trials in |
|---|---|---|---|---|---|
| Bramshill-Elvetham | Hants. | Sand | 4.8 | 7 | 1955 |
| Bramshill-Yateley | Hants. | Sand | 4.7–5.1 | 22 | 1956 |
| Willingham | Lincs. | Sand | 4.6–4.8 | 24 | 1952, 53, 54 |
| Pembrey | Carms. | Sand | Variable; 4.3 (1953) 5.5 (1954), 7.2–7.3 (1955) | 23 | 1952, 53, 54, 55 |
| Kinver | Staffs. | Loamy sand | 3.7–4.8 | 7 | 1952, 53, 54, 55 |
| Laughton | Lincs. | Loamy sand | Not tested | 15 | 1951 only |
| Ringwood-Ferndown | Dorset | Sandy loam | 4.6 (1954) 5.2–5.4 (1955) | 10 | 1954, 55 |
| Ampthill | Beds. | Sandy loam | 6.2–6.4 | | 1954, 55, 56 |
| Tintern–Fairoak | Monmouth | Sandy | 7.0–7.4 | 15 | 1955, 56 |
| Tintern–Trellech | Monmouth | Sandy | 4.0 | 4 | 1952 |
| Newborough | Anglesey | | | | |
| Menai-Tir Forgan | (Caerns.) | Sandy | 5.5–5.8 | 8 | 1952, 53, 54 |
| Menai-Parc Mawr | | Sandy | Not tested | | 1952 |
| Menai-Gweningaer | | Sandy | Not tested | | 1952 |
| Sherwood–Clipstone | Notts. | Sandy | Not tested | | 1951 |
| Dean–Purples | Glos. | Loam | Variable 3.9–4.4 (1952 & 53), 6.3 (1954), 4.7–4.9 (1955) | 8 | 1952, 53, 54, 55 |
| Delamere | Ches. | Loam | 5.2–6.5 | 40 | 1951, 52, 53, 54, 55 |
| Aldewood (Tunstall) | Lincs. | Loam | 5.5–7.0 | 8 | 1952, 53 |
| Longtown | Cumb. | Loam | Variable 4.0–6.9 (1952) 5.0–5.1 (1953 & 54). | 9 | 1952, 53, 54, 56 |
| Slebech | Pemb. | Loam | 4.3 | 6 | 1953 |
| Kerry | Rad. | Loam | Not tested | | 1952 |
| Tair Onen | Glam. | Loam-silt loam | 6.6–7.0 | 19 | 1952, 53, 54, 55 |
| Savernake | Wilts. | Silt loam | 4.1–4.9 | 17 | 1951, 52, 53, 54, 55, 56 |
| Elwy–St Asaph | Denbigh | Loam–clay loam | 6.0–6.8 | 10 | 1952, 53, 54, 55 |
| Mortimer | Shrops. | Silt loam | 6.5–7.2 | 26 | 1951, 52, 53, 54, 55 |

*Note:* Most of the descriptions of soil texture in column 3 are based on mechanical analysis of samples taken at the time of each trial. The descriptions follow the system mentioned in Section 3.11 of this bulletin, page 11. No samples were taken from the sites used in 1951 nor from some of these used in 1952; where experiments at these sites were confined to these two years the classification of the texture is subjective.

pH values in column 4 were determined in water from the same samples used for mechanical analysis. The samples were taken in late winter from the top 5 to 6 inches/12.5 *to* 15 *cm* of soil at the actual trial sites.

## Introduction

Experiments starting in Scotland in 1945 (Edwards, 1953) and in England in 1946 (Crowther 1950, 1951, Crowther and Benzian 1952) showed that certain neutral or slightly acid nursery soils on which Sitka spruce seedlings grew badly, could be made to produce vigorous seedlings by partial sterilisation with formalin in conjunction with a suitable fertiliser treatment.

This response was of great importance because at that time there was no evidence on which to predict the life of the then recently formed heathland nurseries. If these were to become unthrifty after a short period of years, a treatment which could, in effect, restore the productivity of the older nurseries would be invaluable. Such a technique might also be used to raise seedling yields to an acceptable level in those older nurseries where large sums of capital invested in houses for workers etc, would be lost if the nursery were to be closed on grounds of poor productivity.

In 1951 and 1952, therefore, the effect of formalin was tested on a range of species in the more important long-established Conservancy nurseries in England and Wales. The trials were repeated over a period of six years. The first two years' trials were disappointingly unsuccessful and the later trials were undertaken to find out whether the early lack of success was due to faulty technique of application or to genuine inability of seedlings to respond in the nurseries concerned. Treatment with chloropicrin was added as a further comparison in 1954 following favourable results in intensive experiments (Crowther *et al.* 1954).

## Sites

The main characteristics of the nurseries where trials were made each year are shown in Table 47.

### Formalin Drench

Formalin drench using 38–40 per cent formaldehyde solution was applied following the standard technique described in Section 7.14 of this bulletin, at the rates set out in table 48.

In 1952 and 1953, extra water to seal in vapour was applied half an hour after the main application.

TABLE 48
RATE OF FORMALIN APPLICATION 1951–1956

| Year | Vol. of concentrated formalin (38% solution) applied | | Volume of water applied as seal | |
|---|---|---|---|---|
| | *Gallons per yd²* | *Litres per m²* | *Gallons per yd²* | *Litres per m²* |
| 1951 | 0.10 | 0.54 | None | — |
| 1952 | 0.05 | 0.27 | 0.5 | 2.7 |
| 1953 | 0.05 | 0.27 | 0.5 | 2.7 |
| 1954 | 0.05 | 0.27 | None | None |
| 1955 | 0.033 | 0.18 | | |
| | 0.067 | 0.36 | None | None |
| | 0.10 | 0.54 | | |
| 1956 | 0.044 | 0.24 | None | None |

Between 1951 and 1954, the rate selected was the one considered to be optimum on the basis of earlier detailed experiments. In 1956, the rate selected was the highest that could be injected by the Auchincruive injector.

### Formalin Spray

Undiluted formalin (38 per cent) was sprayed through a fine jet onto the surface of the soil at the rate of 0.044 gallons per sq yard/*0.24 l per m²*. This treatment was applied in the 1955 trials only, following indications that this method of application might be as effective as a drench.

### Formalin Injection

Undiluted formalin was drilled in by a tractor-mounted 'Auchincruive' injector at the rate of 0.044 gallons per square yard/*0.24 l per m²*. This injector delivered 8 traces or drills of liquid 5 inches/*12 cm* apart and 2 inches/*5 cm* below the soil surface. A light roller was drawn behind to firm the soil and close the slits left by the drill tines. This treatment was included only in the 1956 trials, again following indications that the technique might be effective.

Both this and the previous treatment were tested in attempts to find a method of using formalin which did not require water. Most forest nurseries do not have a ready water supply and it was anticipated that bringing in water would be both tedious and expensive.

### Chloropicrin Injection

Chloropicrin was injected into the soil by 'Fumigun' injector (see photo 4, page 72, *Rep. For. Res.* 1955). 16 injection points per square yard/*20 per m²* were spaced at approximately 9 inch/*23 cm* centres, 2 ml of liquid being injected at each point to a depth of six inches/*15 cm*. All injection holes were firmly plugged with soil immediately after withdrawal of the injector.

In 1956, chloropicrin was also applied by Auchincruive injector, delivering 4 traces or drills, 9 inches/*23 cm* apart and 6 inches/*15 cm* below the soil surface. The soil was firmed by a light roller following closely behind the tines.

Chloropicrin was applied at the rate of 35 gallons per acre/*400 l per ha* whether injected by hand or machine.

## Date of sowing

In all trials, seed was sown not less than 20 days after the application of formalin or chloropicrin.

## Results

Table 49 below shows, for each year, the number of occasions where treatment with formalin or chloropicrin brought about a significant increase or decrease in height or numbers of plants.

In 1951 and 1952, treatments were applied in late spring and responses to formalin were poor; in subsequent years when treatments were applied earlier, significant height increases were obtained in about two-thirds of the experiments. This difference in responses between 1951/52 and subsequent years is thought to be due to differences in the date of application.

TABLE 49

SUMMARY OF RESPONSES BY 1 + 0 SEEDLINGS TO FORMALIN AND CHLOROPICRIN IN FORESTRY COMMISSION NURSERIES 1951–1956

| Year | Date of treatment | Number of applications. (sites × species) | Number of Significant Responses— To Formalin Increase No. | Ht. | Decrease No. | Ht. | To Chloropicrin Increase No. | Ht. | Decrease No. | Ht. | Species Sown |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1951 | April | 22 | 0 | 2 | 4 | 3 | Not applied | | | | SS, NS, SP, DF, JL. |
| 1952 | End Mar–April | 52 | 0 | 14 | 2 | 1 | " | " | | | SS, NS, DF, SP, CP, PC |
| 1953 | Jan–February | 26 | 4 | 17 | 3 | 1 | " | " | | | SS, NS. |
| 1954 | Feb–March | 26 | 1 | 20 | 2 | 0 | 1 | 18 | 4 | 3 | SS, NS. |
| 1955 | Feb–March | 24 | 1 | 16 | 1 | 1 | 0 | 18 | 1 | 0 | SS. |
| | Feb–March Spray | 24 | 0 | 8 | 1 | 0 | Not applied | | | | SS. |
| 1956 | March | 6 | 0 | 4 | 0 | 0 | 0 | 4 | 1 | 0 | SS. |
| | March Injection | 30 | 1 | 6 | 0 | 0 | 3 | 12 | 0 | 1 | SS, NS, DF, PC, Ab.gr. |

*Note:* Except where marked 'spray' or 'injection', all responses to formalin are to drench applications.

**Species**

The experiment in 1951 and 1952 included several common conifer species, as shown in the last column of Table 49. In these two years' experiments, responses generally were small or absent and there was no indication that one species was more responsive to formalin than any other. In subsequent three years, work was confined mainly to Sitka spruce, being the species used in the work leading up to these trials.

**Height Responses**

Where significant responses occurred, the increases in height due to formalin drench and to chloropicrin injected by hand were similar and were mostly in the range 0.15 to 0.80 inches/*0.4 to 2.0 cm*, or a 10 to 65 per cent increase over the height of the seedlings on untreated plots. This order of height increase has the maximum effect on the number of usable seedlings where untreated seedlings average a little more than one inch/*2.5 cm*, as was the case in the majority of these trials. (A usable seedling is one big enough to be transplanted in large-scale practice, i.e. 1½ inches/*4 cm* or more tall).

The only year when the effect of rates of formalin could be compared was 1955. In this year only in three trials out of 24 was the height growth of seedlings on plots given formalin at 0.1 gallons per square yard significantly better than that on plots treated at the lower rates of application.

Formalin sprayed on the soil surface proved consistently less effective than would be expected from the same amount of formalin applied as a drench. Formalin injected in drills into the soil was also ineffective. These results confirm the need for water as a diluent for the formalin.

Chloropicrin drilled into the soil by Auchincruive injector also was less effective than when injected in discrete doses to a restricted number of points. The depth of injection was much the same and the only obvious explanation of the difference in response is that the soil was far more disturbed by the passage of the tines than where the hand injector had been used, and that the chloropicrin vapour escaped too quickly through the disturbed soil. This hypothesis could also account for the reduced efficiency of the formalin injected in drills.

**Responses in the Number of Plants**

There were few significant increases in seedling numbers following formalin drench treatment and these were balanced by the number of significant reductions in seedling numbers. There were no obvious characteristics common to the nurseries where increases occurred. However, reductions in plant numbers (and also depressions of height growth) occurred more frequently in nurseries where the soil was heavy in texture or where the water table was high. In all cases, at least three weeks elapsed between treatment and sowing, but it may be that for certain types of soil, this interval is not long enough.

**The Effect of Site on Response to Formalin or Chloropicrin**

In the results of the 1953 trials, there was a suggestion that responses were smaller on ground that had been fallow in the year preceding treatment than on ground cropped in the previous year. This possibility was tested in 1955 when trials were repeated on sites where fallow and cropped ground could be found side by side, but there was no indication of any consistent difference one way or the other.

There was also a suggestion from the 1952 and 1953 trials that responses could be related to soil texture. Table 50 lists nurseries according to the texture of the soil, showing, for each nursery, the number of significant height increases in relation to the number of experiments. The nurseries with medium texture soils (sandy loams and loams) appear to have benefited regularly from formalin and chloropicrin; the lighter soils were somewhat less regular in response while on the heavy soils, height increases were obtained little more often than one year in two.

Formalin had no obvious advantage over chloropicrin on any particular site type or vice versa.

TABLE 50

NURSERIES LISTED BY SOIL TEXTURE SHOWING THE MAGNITUDE OF INCREASES IN HEIGHT OF SITKA SPRUCE FOLLOWING SOIL APPLICATIONS OF FORMALIN (FN) AND CHLOROPICRIN (CPN) AND THE NUMBER OF INCREASES OBTAINED

| Nursery | (1) Texture | pH | Magnitude of height increase by Sitka spruce following treatment with Formalin | Chloropicrin | (2) Number of expts. (years × sites) (Fn) | (Cpn) | No. of significant height increases (Fn) | (Cpn) |
|---|---|---|---|---|---|---|---|---|
| | | | inches increase | inches increase | | | | |
| Willingham | Sand | 4.6–4.8 | .4 | .8 | 3 | 1 | 1 | 1 |
| Pembrey | Sand | Variable 4.3–7.4 | .3– .6 | .6– .7 | 4 | 3 | 3 | 2 |
| Kinver | Loamy sand | 3.7–4.4 | .2– .7 | .2 | 5 | 3 | 3 | 1 |
| Ringwood–Ferndown | Sandy loam | 4.6–4.7 | 1.0 | — | 3 | 3 | 1 | 0 |
| Ampthill | Sandy loam | 6.3–6.9 | .4– .9 | .3– .7 | 4 | 4 | 3 | 3 |
| Dean–Fair Oak | Sandy loam | 7.0–7.4 | .3– .5 | .2– .7 | 3 | 3 | 3 | 3 |
| Newborough | Sandy loam | 5.5–5.8 | .2– .6 | .4– .6 | 2 | 1 | 2 | 1 |
| Dean–Purples | Loam | Variable 3.9–6.3 | .2– .5 | .3–1.0 | 4 | 3 | 3 | 3 |
| Delamere | Loam | 5.1–6.5 | .4 –.7 | .3– .5 | 6 | 3 | 5 | 3 |
| Longtown | Loam | Variable 4.0–6.9 | .6 | — | 4 | 2 | 1 | 0 |
| Tair Onen | Loam-silt loam | 6.9–7.0 | .2– .3 | .2– .6 | 6 | 4 | 3 | 3 |
| Savernake (3) | Silt loam | 4.1–4.9 | .4–1.1 | .3– .9 | 7 | 3 | 5 | 3 |
| Elwy | Loam-clay loam | 6.2–6.8 | .3 | .6 | 5 | 3 | 1 | 1 |
| Mortimer | Silt loam | 7.0–7.2 | .2– .3 | .4– .7 | 6 | 3 | 3 | 3 |

*Notes:* (1) Nurseries in which experiments were made in one year only have been omitted.

(2) The 1955 experiment, each on fallow and cropped areas, have been counted as two sites at each nursery.

(3) Though there were significant height increases at Savernake, there were also, in most years, significant reductions in numbers.

## Conclusions

At the end of 1956, the conclusions to be drawn from these trials were:

(1) Formalin drench or chloropicrin applied in late winter could be expected to increase the average height of spruce seedlings by at least 0.3 to 0.5 inches/*1 to 1.5 cm* in nurseries where the soil was a light to medium loam. These increases were sufficient to enable seedbeds to be lifted and seedlings lined out after one year which otherwise would have to remain for two years.

(2) It is essential to apply formalin or chloropicrin not later than February in each year.

(3) On heavy and light soils, responses were less reliable.

(4) There was no clear evidence that response was affected by previous cropping history.

(5) There was no evidence on which to recommend one partial sterilant in preference to the other.

(6) An interval of three weeks between treatment and sowing appears adequate except where the soil i heavy or where there is a high water table.

Since the completion of these trials, heathland nurseries have continued to be highly productive, the only limitation to their life being imposed by increasing weediness. Consequently, there has been little call in general practice for the use of either material; formalin has been used regularly only in a few older Scottish nurseries, and these are in areas where true heathland nursery sites are not available.

### EXPLANATORY NOTE

These trials were arranged after discussion and with the approval of the Committee on Nutrition Problems in Forest Nurseries (a sub-committee of the Research Advisory Committee). This sub-Committee asked that the results of the trials be summarised and made available to be read along with the account of those experiments laid down under their auspices which gave rise to these trials. The results of these latter experiments are described in Forestry Commission Bulletin 37. *Nutrition Problems in Forest Nurseries, Vol.* 1, B. Benzian, 1965.

REFERENCES

CROWTHER, E. M. 1950. Nutrition Problems in Forest Nurseries. Summary Report on 1948 Experiments. *Rep. Forest Res., Lond.* 1949. 60–64.

CROWTHER, E. M. 1951. Nutrition Problems in Forest Nurseries. Summary Report on 1949 Experiments. *Rep. Forest Res., Lond.* 1950. 97–105.

CROWTHER, E. M. and BENZIAN, B. 1952. Nutrition Problems in Forest Nurseries. Summary Report on 1950 Experiments. *Rep. Forest Res., Lond.* 1951. 113–122.

CROWTHER, E. M. *et al.* 1954. Nutrition Problems in Forest Nurseries. Summary Report on 1952 Experiments. *Rep. Forest Res., Lond.* 1953. 84–99.

EDWARDS, M. V. 1952. *The Effects of Partial Soil Sterilization with Formalin on the Raising of Sitka spruce and other Conifer Seedlings.* Forest Rec., 13. Lond.

## Appendix VII

### Common and Botanical Names of Conifers

| *COMMON NAME* | *CURRENT BOTANIC NAME* |
|---|---|
| Cypress | |
| Lawson cypress | *Chamaecyparis lawsoniana* (A. Murray) Parl. |
| Leyland cypress | × *Cupressocyparis leylandii* (Jacks. & Dall.) Dall. |
| Monterey cypress | *Cupressus macrocarpa* Gord. |
| Nootka cypress | *Chamaecyparis nootkatensis* (D. Don) Spach |
| Douglas fir | *Pseudotsuga menziesii* (Mirb.) Franco. |
| Fir | |
| Grand fir | *Abies grandis* Lindl. |
| Noble fir | *Abies procera* Rehder |
| Silver fir | *Abies alba* Mill. |
| Hemlock | |
| Western hemlock | *Tsuga heterophylla* (Rafinesque) Sarg. |
| Larch | |
| European larch | *Larix decidua* Mill. |
| Hybrid larch | *Larix* × *eurolepis* Henry |
| Japanese larch | *Larix kaempferi* Carr. |
| Maidenhair tree | *Ginkgo biloba* L. |
| Monkey puzzle | *Araucaria araucana* (Molina) Koch |
| Pine | |
| Austrian pine | *Pinus nigra* Arnold var. *nigra* Harrison. |
| Corsican pine | *Pinus nigra* Arnold var. *maritima* Melville. |
| Lodgepole pine | *Pinus contorta* Loud. |
| Monterey pine | *Pinus radiata* D. Don |
| Mountain pine | *Pinus mugo* Turra |
| Scots pine | *Pinus sylvestris* L. |
| Redwood | |
| Californian redwood | *Sequoia sempervirens* (Lamb.) Endl. |
| Dawn redwood | *Metasequoia glyptostroboides* Hu & Cheng |
| Spruce | |
| Norway spruce | *Picea abies* (L.) Karst. |
| Serbian spruce | *Picea omorika* Purkyne |
| Sitka spruce | *Picea sitchensis* (Bong.) Carr. |
| Wellingtonia | *Sequoiadendron giganteum* (Lindl.) Buch. |
| Western red cedar | *Thuja plicata* Lamb. |
| Yew | *Taxus baccata* L. |

## Appendix VIII

### Common and Botanical Names of Broadleaved Trees

| *COMMON NAME* | *CURRENT BOTANIC NAME* |
|---|---|
| Alder | |
| Common alder | *Alnus glutinosa* (L.) Gaert. |
| Green alder | *Alnus cordata* Desfont. |
| Grey alder | *Alnus incana* (L.) Moench. |
| Red or Oregon alder | *Alnus rubra* (Bong.) |
| Ash | *Fraxinus excelsior* L. |
| Beech | *Fagus sylvatica* L. |
| Birch | |
| Paper birch | *Betula papyrifera* Marsh. |
| Hairy birch | *Betula pubescens* Ehrh. |
| Silver birch | *Betula pendula* Roth. |
| Broom | *Sarothamnus scoparius* (L.) Wim. |
| Cherry | |
| Bird cherry | *Prunus padus* L. |
| Gean or Wild cherry | *Prunus avium* L. |
| Chestnut | |
| Horse chestnut | *Aesculus hippocastanum* L. |
| Sweet or Spanish chestnut | *Castanea sativa* Mill. |
| Elm | |
| English elm | *Ulmus procera* Salis. |
| Smooth leaved elm | *Ulmus carpinifolia* Gled. |
| Wych elm | *Ulmus glabra* Huds. |
| False acacia | *Robinia pseudoacacia* L. |
| Hawthorn | *Crataegus monogyna* Jacq.<br>*C. oxycanthoides* Thuill. |
| Hazel | *Corylus avellana* L. |
| Hickory | *Carya* spp. |
| Holly | *Ilex aquifolium* L. |
| Hornbeam | *Carpinus betulus* L. |
| Horse chestnut—see Chestnut | |
| Indian bean | *Catalpa bignonioides* Walt. |
| Lime | |
| Large-leaved lime | *Tilia platyphyllos*, Scop. |
| Small-leaved lime | *Tilia cordata* Mill. |
| Common lime | *Tilia europea* L. |
| Maple and sycamore | |
| Field maple | *Acer campestre* L. |
| Norway maple | *Acer platanoides* L. |
| Sycamore | *Acer pseudoplatanus* L. |

| *COMMON NAME* | *CURRENT BOTANIC NAME* |
|---|---|
| Oak | |
| Pedunculate oak | *Quercus robur* L. |
| Red oak | *Quercus borealis* Michx. f. |
| Sessile oak | *Quercus petraea* (Matt.) Liebl. |
| Turkey oak | *Quercus cerris* L. |
| Plane | |
| Buttonwood | *Platanus occidentalis* L. |
| London plane | *Platanus* ×*acerifolia* (Ait.) Willd. |
| Oriental plane | *Platanus orientalis* L. |
| Poplar | |
| Aspen | *Populus tremula* L. |
| Black | *Populus nigra* L. |
| Grey | *Populus canescens* Sm. |
| White | *Populus alba* L. |
| Hybrid balsam poplars | Cultivars of *P. tacamahaca* × *P. trichocarpa* |
| Hybrid black poplars | Cultivars of *P.* ×*'euramericana'* |
| Rowan and Whitebeam | |
| Rowan | *Sorbus aucuparia* L. |
| Whitebeam | *Sorbus aria* (L.) Crantz |
| Swedish whitebeam | *Sorbus intermedia* (Ehrh.) Pers. |
| Southern beech | |
| Roble | *Nothofagus obliqua* (Mirb.) Blume |
| Rauli | *Nothofagus procera* (Pop. & End.) Oerst. |
| Spindle | *Euonymus europaeus* L. |
| Sweet or Spanish chestnut—see Chestnut | |
| Sycamore—see Maple | |
| Tree of heaven | *Ailanthus altissima* (Mill.) Swingle |
| Tulip tree | *Liriodendron tulipifera* L. |
| Walnut | |
| Black walnut | *Juglans nigra* L. |
| Common walnut | *Juglans regia* L. |
| Willows | |
| Basket willows | *Salix purpurea* L.<br>*Salix triandra* L.<br>*Salix viminalis* L. |
| Cricket bat willow | *Salix alba* var. *coerulea* Sm. |

## Appendix IX

## Seed Identification Numbers

The purpose of this note is to explain the objects of the system now used by the Forestry Commission, what it means and how it works. A list of the most important seed identity numbers is given for reference purposes and two maps illustrate the way the numbers are applied in Britain and the north-western American coastal region.

The ultimate aim of the work being done on the many aspects of seed supplies in Britain is to ensure that all the seed used in British forestry comes from selected seed trees growing on specified areas. It will require many years of continuous effort to reach this goal and at present seed lots and the plants derived from them are of four kinds, (1) General Seed Collections; (2) Collections from certain Specified Areas and Stands Classified as "Plus"; (3) Collections of Local Interest; (4) Research Division Collections.

### The Objects of the Code

The permanent seed identification code is linked with the maintenance of the Register of Seed Sources for both home collected and imported seed. This register contains details of classified seed sources in Britain and as time goes on will provide similar information for seed sources abroad. The register is being added to each year and it is desirable that it should be set out in a systematic manner using a seed identification code system which is (1) readily applicable to both home collected and imported seed, (2) capable of expansion, (3) readily indicates the origin of the seed or plants, (4) consists entirely of numerals for convenience in keeping records.

Seed used in British forestry both for large scale planting and for research purposes, comes from very widely scattered areas of the world and there are obvious advantages in using an existing system of numbers. The one selected is the Universal Decimal Classification, published by the British Standards Institution, which gives place numbers for the majority of the countries of the world. Figures 14 and 15 illustrate the principle. The way in which the Universal Decimal Classification has been adapted for seed identification purposes is as follows:

*The first digit within the brackets* indicates Continents: e.g. (4) Europe.

*The second digit within the brackets* indicates larger countries and major Political Divisions: e.g. (42) England and Wales.

*The third digit within the brackets* indicates small countries and larger Provinces, Regions and Zones: e.g. (421) South-East England.

*The fourth digit within the brackets* indicates British Counties, French Departments, etc. and small States, Provinces and Zones: e.g. (4215) Sussex. These numbers are used for 'general' collections.

General seed collections are those in which seed has been collected over considerable areas (e.g. Douglas fir from several seed collection points in the northern coastal region of Washington, USA) or from a number of stands which are of normal (i.e. average) quality or are unclassified (e.g. beech from several stands in eastern England). These collections are made to meet specific demands and the collection areas or the seed trees or both are more or less unselected. These general collections are bulked together in the central seed store at Alice Holt into large lots, mainly to reduce unnecessary record keeping and for practical working. The seed identity numbers used consist of two, three or four figures within the brackets, e.g. DF.58 (7971) describes Douglas fir seed of the crop year 1958 collected at two or more collection areas in the northern coastal region of Washington.

*One or two digits outside the brackets* indicate seed collection areas or classified seed sources which are considered to be important for practical purposes.

Collections from certain specified areas and stands classified as 'Plus' are kept separate and given a distinguishing suffix number outside the brackets when the varieties associated with these areas or stands are known to be or show promise of being of practical value. For plus seed sources in Britain both the boundaries of the stand and the characteristics of the trees are known and described, e.g. Be. 58 (4215) 1 Slindon Wood, Slindon Park Estate; whereas a good variety from abroad may only be identified at present by means of a place name, e.g. DF. 58 (7974) 5 Darrington. Most forest services in Europe and elsewhere are now building up Registers of Seed Sources and at least one American seed firm also markets seed for which both the area of collection and quality of seed trees are guaranteed. This kind of seed lot should become more common as time goes on. Seed collected from seed orchards will also receive the suffix numbers to distinguish the varieties permanently.

*Three digits outside the brackets* indicate a Research Division Collection made for experimental purposes only: e.g. (4215) 100 a single tree within Slindon Wood.

When seed or plants from any seed source are distributed, the seed identity code number is accompanied by two additional items of information which are also coded (1) the species name (in abbreviated form) and, (2) the crop year, i.e. the year in which the cones, fruit or seed have ripened. Thus, for example, Be.58 (4215) 1 describes mast collected in the crop year 1958 from the Plus Stand of beech in Slindon Wood on the Slindon Park Estate and the full details of the boundaries of the stand and the quality of the trees can be found under (4215) 1 in the Register of Seed Sources.

Because the identity numbers are permanent all mast collected in any year from this seed source receive the same identity number, e.g. Be. 60 (4215) 1 and so on.

Small collections of local interest are small quantities of seed (e.g. 2½ lb of beech, 5 lb of acorns or less than 1 lb of conifer seed) collected from single trees or small groups of trees of local interest. It is not necessary to apply the full recording procedure to such seed lots unless there is a special reason for so doing.


Fig. 14. Seed Collection Zones in Great Britain.

**How the Code Numbers are Allocated**

Code numbers for imported seed are allocated at the Central Seed Store at Alice Holt, Wrecclesham, near Farnham, Surrey, which handles all seed imported by the Forestry Commission.

Code numbers for home collected seed should all be found in the Commission's Register of Seed Sources, copies of which are held by each Conservator. For addresses, see Appendix II, page 144.

**A Summary of Essential Information**

The permanent seed identification code system was devised to enable the comprehensive Register of Seed Sources to be compiled and added to over a long period of years.

General seed collections receive identity numbers within the brackets; Collections from specified areas or stands classified as "plus" receive one or two distinguishing suffix numbers outside the brackets; Research Division collections are further distinguished by three digits outside the brackets. The last two digits of the year in which the seed ripens form a prefix to the number in brackets.

*A list of the most important Seed Identity numbers follows on page 169.*

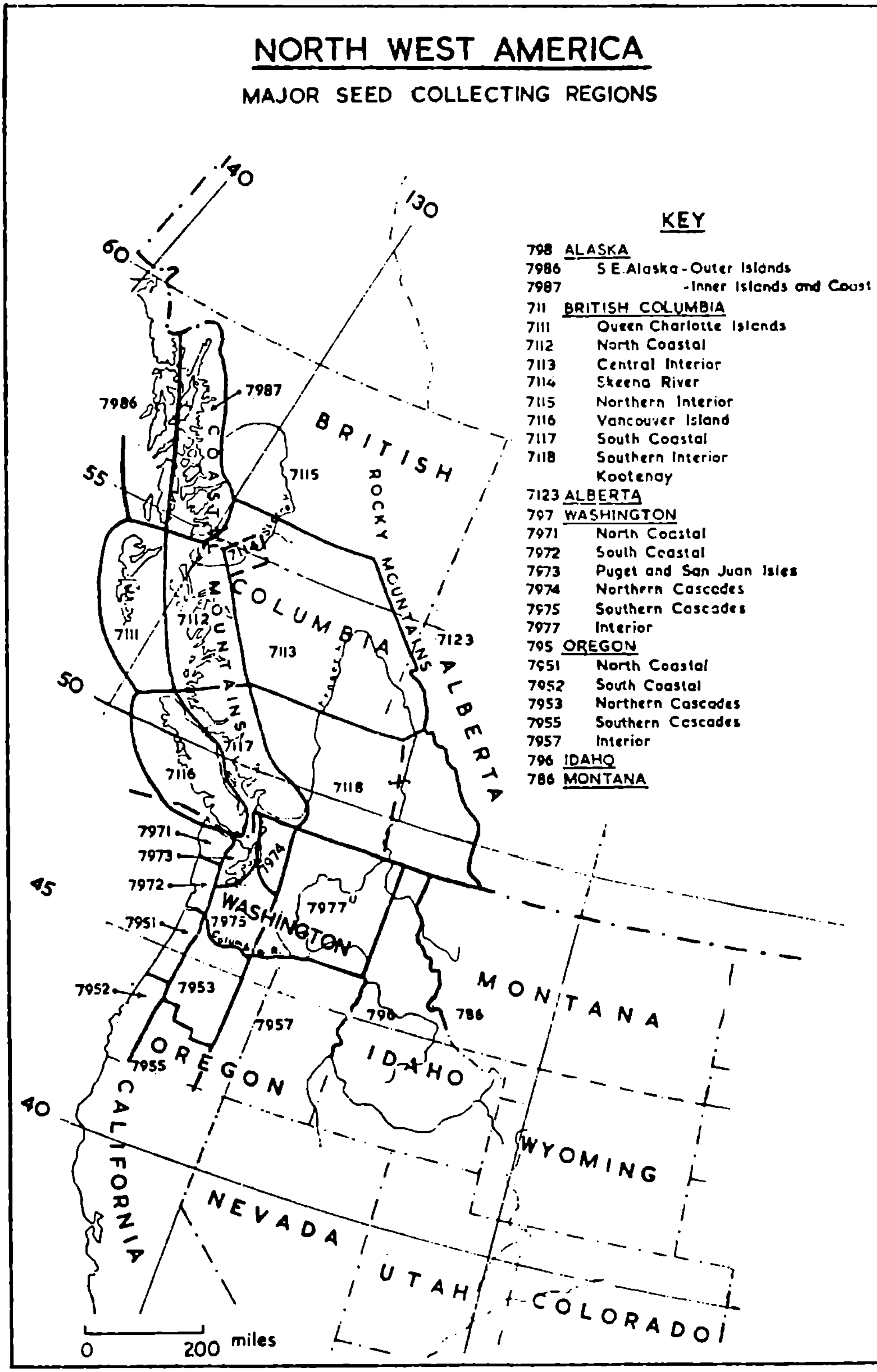



Fig. 15. Seed Collection Zones in Western North America.

*Appendix IX—cont.*

(4) EUROPE

(41) Scotland. (See Fig. 14, p. 166 for details).
(415) Ireland in general
(416) Northern Ireland.
(417) Eire.
(42) England. (See Fig. 14 for details).
(4279) Isle of Man.
(428) North Wales. (See Fig. 14 for details).
(429) South Wal es. (See Fig. 14 for details).
(43) Germany.
(431) North-eastern Germany and Prussia.
(432) Central Germany.
(433) South-eastern Germany, Bavaria.
(434) Southern Germany.
(435) North-western Germany.
(4359) Luxemburg.
(436) Austria.
(437) Czechoslovakia.
(438) Poland.
(439) Hungary.
(44) France.
(45) Italy.
(458) Sicily and Adjacent Islands.
(4599) Corsica.
(46) Spain.
(469) Portugal.
(47) Union of Soviet Socialist Republics.
(472) Northern Russia.
(473) Central Russia.
(474) Baltic States.
(476) Western Russia; Belorussian SSR.
(497) Southern Russia. Ukraine, Crimea.
(478) Eastern Russia.
(479) Caucasia and Transcaucasia.
(480) Finland.
(481) Norway.
(485) Sweden.
(489) Denmark.
(492) Netherlands (Holland).
(493) Belgium.
(494) Switzerland.
(495) Greece.
(4971) Jugoslavia.
(4972) Bulgaria
(498) Romania.

(5) ASIA.

(51) China.
(512) South-east and Central China.
(513) South-west China.
(518) Manchuria.
(519) Korea.
(52) Japan.
(521) Honshiu (Nippon).
(5215) West Central Honshiu (including Nagano).
(522) Kiushiu (Kyushu).
(524) Hokkaido (Yezo).
(527) Kurile Islands.
(5291) Formosa.
(540) Republic of India.
(549) Pakistan.

*Appendix IX—cont.*

(55) Iran (Persia).
(560) Turkey.
(5643) Cyprus.
(567) Iraq.
(5691) Syria.
(5694) Israel.
(57) Siberia and Soviet Far East.
(571) Western Siberia.
(572) Central Siberia.
(573) Eastern Siberia.

(6) AFRICA.
(61) North and North-east Africa.
(65) Algeria.
(68) South Africa.

(7) NORTH AMERICA. (See Fig. 15, p. 168, for details of main areas).
(71) Canada.
(711) British Columbia (See Fig. 15 for details).
(7123) Alberta.
(7124) Saskatchewan.
(7127) Manitoba.
(713) Ontario
(714) Quebec.
(715) New Brunswick.
(716) Nova Scotia.
(717) Prince Edward Island.
(718) Newfoundland.
(719) Labrador.
(72) Mexico.
(73) United States of America.
(74) North-east USA, New England.
(75) South-east USA South Atlantic States.
(76) South Central USA, Gulf States.
(77) North Central USA, and Lake States.
(78) Western States of America Rocky Mountain Region.
(79) Pacific States of America.
(791) Arizona.
(792) Utah.
(793) Nevada.
(794) California.
(795) Oregon. (See Fig. 15 for details).
(796) Idaho.
(797) Washington. (See Fig. 15 for details).
(798) Alaska. (See Fig. 15 for details).

(8) SOUTH AMERICA.
(83) Chile.

(9) OCEANIA.
(931) New Zealand.
(94) Australia.

# INDEX

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