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CHALK DOWNLAND AFFORESTATION

By

R. F. WOOD, B.A., B.Sc. and M. NIMMO

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LONDON: HER MAJESTY'S STATIONERY OFFICE

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FOREWORD

The substantial areas of chalk downs and wolds which are found in the south and east of England include many tracks of land well suited to afforestation. But the peculiar characters of the bedrock and its superficial soils present many problems, which have occupied the attention of the Forestry Commission's staff since it made its first acquisition of a chalk downland area, at Friston Forest in Sussex, in 1927. The Commission has now (1961) over 30 forests situated wholly or partly on chalk formations, scattered over the southern and eastern counties from Dorset to Kent and north to Yorkshire, while private estate owners are also engaged in the planting and management of extensive stretches of chalk down woodland.

In 1927 the Commission began a series of experiments into the best methods to use, and the most suitable kinds of trees to plant, on chalk downs and wolds undergoing afforestation for the first time.

These trials, most of which are centred on Friston Forest, near Eastbourne in Sussex, and Queen Elizabeth Forest near Petersfield in Hampshire, have been continued ever since, and the main purpose of this Bulletin is to present the findings to date. It also includes an account of the characteristics of the chalk country, a historical review of planting practice since 1808, and a discussion of the future prospects.

It is written by Mr. R. F. Wood and Mr. M. Nimmo, two Forest Officers in the Commission's Research Branch, who have had many years experience of the problems and methods discussed.

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NOTES

(1) Throughout this text, capitals as in "Chalk", are used to denote a specific geological formation, and small initial letters, as in "chalk", a type of soil or rock.

(2) All the photographs are drawn from the Commission's own collection.

Chapter 1

INTRODUCTORY

The area represented by the Chalk on a 'solid' geological map is some 5,000 square miles, or about one tenth of the land surface of England. (Fig. 1). Chalk does not occur in Wales or Scotland, except for a tiny outcrop in the Isle of Mull.

Other calcareous rocks outcrop over a somewhat larger area, but though certain of the limestones give rise to soils similar to those derived from the Chalk, it is the latter formation which provides the best and most extensive examples of soils dominated or strongly influenced by calcareous materials.

Salisbury (1952) in comparing the chalk and limestone habitats, observes that limestones (while extremely variable in this respect) generally contain a far greater proportion of insoluble residues than does the Chalk, which is usually 95% or more calcium carbonate. Hence limestone-derived soils are usually deeper and moister than those derived from the Chalk, and they are also much more variable in physical texture. Salisbury (ibid) also comments on the distribution of the chalk and limestone formations. The various limestone formations are to be found to the west and north of the Chalk, and thus generally lie in somewhat moister and/or cooler climates. He notes that 'a line drawn from the Wash to the Bristol Channel . . . . has been shown to mark roughly the northern limit of many southern species even though not associated with calcareous soils', and further, 'it may be said that in this region soil conditions and climate combine to reinforce their respective influence'.

The Chalk outcrops are well known features of the south and east of England, forming the North and South Downs, the Chiltern Hills and the Lincolnshire and Yorkshire Wolds. In addition the Chalk underlies considerable areas of less elevated or more gently rolling terrain, such as Salisbury Plain or the Breckland of Norfolk and Suffolk. As with other rocks, by no means all of the outcrop is represented by soils derived directly from the Chalk; deposits of one sort or another varying greatly in depth cover much of the Chalk, and at the extreme the chalk may have little or no influence on conditions at the surface. It is of course this fact which makes it necessary to be very careful in defining the site.

The Chalk is not a formation of the first importance to foresters. Where the topography is favourable and the soils deep enough, there is much excellent arable land. The downs themselves are traditionally open grazing, and it seems likely that the greater part will remain under agriculture. There has however always been a considerable area of woodland on the Chalk, ranging from the extensive Chiltern woodlands to the small remnants of natural forest to be found on the downland valley slopes. In addition, plantations have been made for many reasons, for shelter, as game preserves, for profit, and sometimes purely for ornament. Whatever the motive, a wood is a wood, and the beauties of mature chalk beechwoods are as frequently extolled as fresh plantations on open downlands are condemned (and often by the same critics).

The subject matter of this report is the afforestation of chalk downland. Most of our experiments, and all our experimental results, have been obtained on southern chalk sites, but some generality may be claimed, since the shallower chalk soils present similar problems whenever they are encountered.

It is somewhat difficult to draw a line which will separate sites which are 'specially' chalk from sites which are on the Chalk, but reflect chalk characteristics and problems to a much lesser degree. Our concern is plainly with soils which are shallow enough for the chalk to have an early and significant influence. This condition is not of course confined to the Downs or Wolds, but it is more common here than in the chalk country of lesser relief. Important problems of calcareous subsoils are also to be met with in East Anglia on the soils delivered from the Chalky Boulder Tills, but these are less pure and normally have greater depths of lime-free material at the surface. A number of useful analogies can be drawn between the Breckland, where extensive afforestation has been carried out in the Thetford area, and the Downlands, but the topography and microclimate of the Breckland are sufficiently distinct to make the afforestation of this type of country a subject in itself.

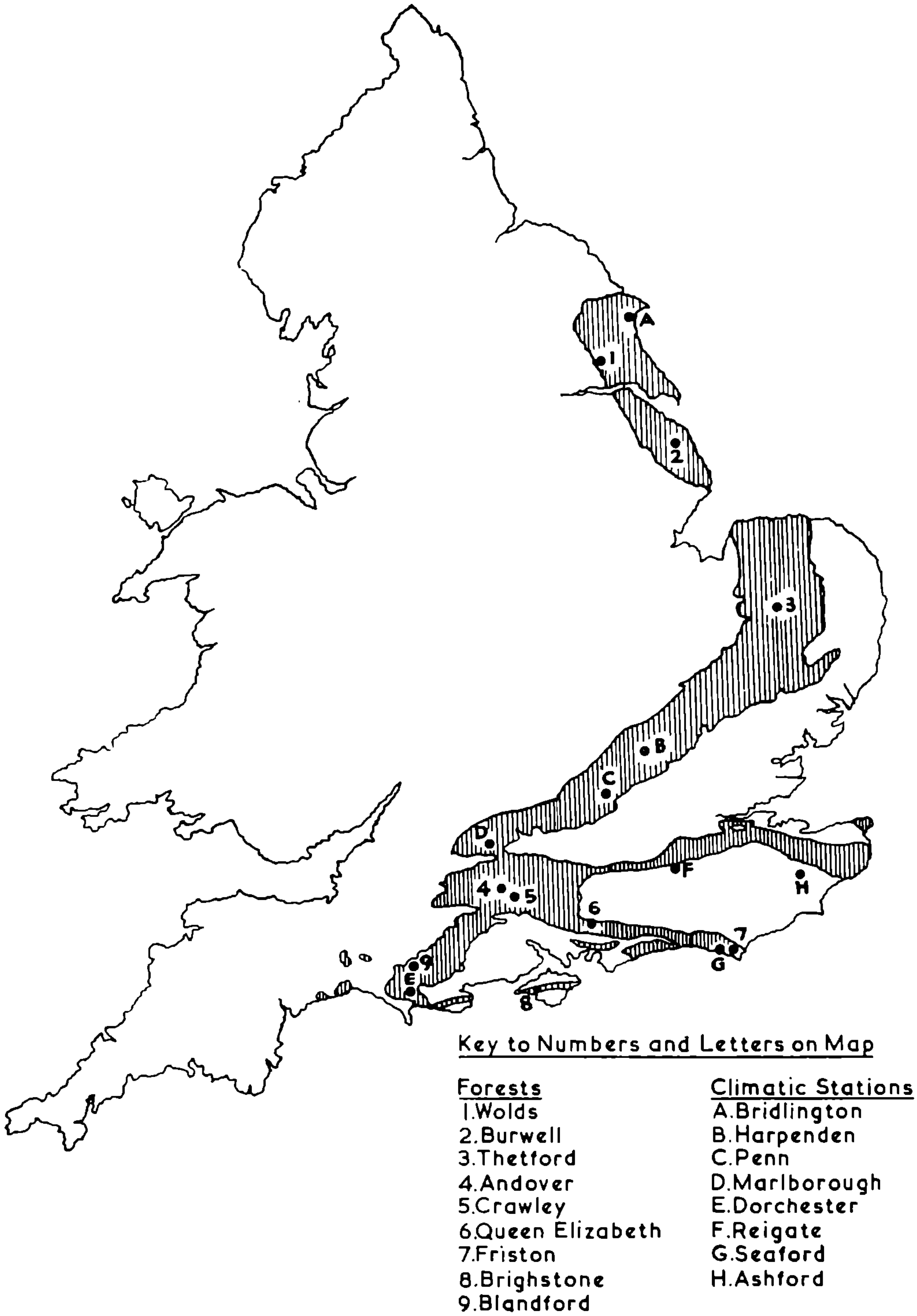

Fig. 1. Distribution of the Chalk in England.

The soils we are concerned with are special in that much of the root growth of trees growing on them lies in a highly calcareous medium, and it must be emphasised at the outset that there can be no greater error than to assume that, because the underlying rock happens to be chalk, the trees can be said to be growing in a chalk soil. Such assumptions lie behind a number of unfortunate records of species 'doing well on chalk', which have often led to disappointing results when the species really *have* been planted on it. Later investigations may reveal that the trees concerned were growing happily on some two or more feet of Clay-with-flints. It is necessary to be specially careful in interpreting the behaviour of young trees, since it is not only the depth of rootable soil over the chalk which is of importance, but the presence or absence of free lime in the top few inches. This is of special significance for most conifers, since the nutritional disorder known as lime-induced chlorosis may be delayed by the presence of quite small amounts of lime-free material.

The Chalk being a very permeable rock, the depth and nature of the soils overlying it greatly influence the water storage capacity, and here again the special character of downland sites is very much a question of the proximity of the chalk to the surface. It is this which makes it so difficult to generalise about downland as an afforestation 'type'.

In this paper, the subject will be treated in a purely practical manner. The geology of the Chalk formations, the genesis of soils and the ecology of downlands have all been the subjects of much study, and reference will be made to a number of such basic studies without any pretence at adding to the fundamental knowledge of this environment. There is probably no site on which it is more important for the forester to pay close attention to the ecological aspects of his work, and it is fortunate that the downlands have attracted the interest of some very able ecologists.

The material for this report has been collected from several sources; the Forestry Commission's own experimental work at Queen Elizabeth and Friston forests, mainly undertaken between 1927 and 1939; the Forestry Commission's general experiences at these and other chalk areas (Troup (1954) has already covered much of this ground in a very concise account); published experiences by private woodland owners; and surveys of chalk woodlands undertaken in connection with the publication *Studies on British Beechwoods* (Brown 1953). Mr. D. Fourt has been of particular assistance on all questions concerned with chalk downland soils. While experimentation on chalk sites has continued and is continuing, it does not represent so large and comprehensive a body of work as that carried out on the more important afforestation types, such as heathland and moorland. There are inevitably gaps in our knowledge, and it is hoped that these are openly displayed. But sufficient has been learned of this subject to warrant setting out what is known, if only to ensure that the more obvious errors need not be repeated.

Chapter 2

SPECIAL CHARACTERS OF CHALK DOWNLANDS

The chalk downland environment has a number of characteristics which, taken together, restrict the choice of species and render the establishment of plantations a slow and somewhat chancy business. At the worst the forester may be confronted with a combination of rapidly draining, non-retentive and calcareous soils, intractable grass swards, and high degrees of exposure.

Little need be said about the general climate of the Chalk regions, except to point to those features of the climate of southern and eastern England which accentuate the characteristics of the Chalk downland environment.

Climate

Most of the Chalk lies in the drier part of England. Annual rainfall for the Chalk south of the Thames ranges from about 40 in. at the western end of the Dorset Downs to 23 in. in the driest parts of the North Downs. These differences of annual rainfall in the southern Chalk areas are undoubtedly of importance, especially for young plantations on the shallowest soils. The general average for the Chalk south of the Thames is approximately 32 in. Monthly rainfall averages for a number of stations on the Chalk are given below (Table 1).
Rainfall in the southern-eastern counties is reasonably evenly distributed over the year. There is a tendency for June to be the driest month, and, as over most of the country, spring (March, April, May) is the driest quarter. The northern Chalk does not experience more rainfall than the southern, but the evaporation rates in Yorkshire are markedly lower than in the counties south of the Thames (Penman 1950). A Yorkshire Wold locality with a rainfall of, say, 30 in. is a moister environment than a South Down locality of the same annual rainfall. The difference may be worth several inches of rainfall.

Much of the southern chalk country, particularly the South Downs, has sunshine records well above the average for the country.

There is little to be said about temperature on a regional basis, though it is perhaps worth comment that the temperature climate of the Yorkshire Wolds is sufficiently cooler than that of the southern chalk regions to effect the behaviour of one important species—Corsican pine.

Topography and Local Climate

The general configuration of chalk downland country is too familiar to require detailed description. While never attaining great elevations, the downs are the dominant features in the landscape. The highest points run to somewhere round the 900 foot level, for example, Milk Hill, Wiltshire, 964 ft.; Bulbarrow Hill, Dorset, 902 ft.; Botley Hill, Surrey, 877 ft.; Butser Hill, near Petersfield, Hants, 889 ft. Much of Salisbury Plain lies between 400 and 600 ft., rising to 754 ft. just east of Westbury, Wilts. The highest point in the Yorkshire Wolds is 808 ft.

Most downland must rank as highly exposed, the severity of this naturally depending on the relative elevation and the aspect. The prevailing wind velocities in the south-east of England are not nearly so great as those of the southwest, and exposure alone is not likely to be limiting to tree growth on any of the downs, though it will undoubtedly restrict height growth considerably. Brown (1953) gives an instance at Goodwood, where an old beech stand growing round a spur under uniform soil conditions, showed a reduction in height from 105 to 78 ft. as the exposure changed from the east to the south-west. It is probable that the principal effects of exposure on the downs are to increase the transpiration stresses on young trees and thus to accentuate the drought factor in establishment. On seaward aspects of the South Downs salt carried by gales off the sea may do considerable damage, particularly to broadleaved trees during summer storms (Edlin 1957, see also Plates 6–8).

Aspect and slope are important as regards the moisture of the site, though their effects may be difficult to distinguish from those of soil characteristics. Perring (1959) has shown that the main 'moisture axis' on isolated downs run south-west to north-east; the driest conditions occurring on steep slopes to the south-west and the moistest on gentle slopes to the north-east.

The frost factor on downland is in great part a matter of local topography, the dry valleys between

TABLE 1: MONTHLY AVERAGES OF RAINFALL FOR A NUMBER OF STATIONS ON THE CHALK

Period 1916-1950 Inches.

Place and County	January	February	March	April	May	June	July	August	September	October	November	December	Annual Totals
Ashford, Kent ..	2.99	2.18	1.89	2.11	2.07	1.58	2.47	2.46	2.24	3.33	3.50	3.09	29.91
Seaford, Sussex ..	2.86	2.00	1.78	1.90	1.73	1.64	2.15	2.50	2.35	3.16	3.58	3.07	28.72
Reigate, Surrey ..	3.17	2.24	2.04	2.53	2.03	1.86	2.57	2.60	2.29	3.16	3.55	3.22	31.26
Andover, Hants. ..	3.20	2.03	1.85	2.08	2.00	1.63	2.67	2.42	2.44	3.07	3.25	3.05	29.51
Dorchester, Hants. ..	4.10	2.88	2.62	2.39	2.36	1.84	2.89	3.03	3.32	4.15	4.71	4.34	38.63
Marlborough, Wilts.	3.41	2.50	2.12	2.47	2.33	1.95	2.86	2.70	2.77	3.42	3.58	3.48	33.59
Penn, Bucks. ..	3.04	2.13	1.89	2.25	2.22	1.85	2.89	2.63	2.62	2.98	3.37	2.85	30.72
Harpenden, Herts. ..	2.59	1.81	1.62	2.00	1.97	1.64	2.56	2.21	2.23	2.55	2.94	2.44	26.57
Thetford, Norfolk ..	2.19	1.61	1.43	1.90	1.80	1.70	2.62	2.38	2.23	2.21	2.44	2.06	24.57
Bridlington, Yorks...	2.67	1.95	1.68	1.91	2.00	1.75	2.38	2.64	2.32	2.56	2.90	2.72	27.48

(With acknowledgements to the Meteorological Office)

high downs frequently providing excellent collecting grounds for the cold air flowing down from the tops. Also the downland sward provides good conditions for radiation frosts in clear still weather (see Plate 9).

Geology and Soils

Of the three divisions of the Chalk (Upper, Middle and Lower), the first represents by far the greatest surface area. It carries flints in bands and nodules, which are usually absent in the other two divisions. Apart from this, there appear to be few important differences between the Upper and Middle Chalk as regards soil formation. The Lower Chalk may be dismissed since it represents a very small surface area.

The lie of the Chalk strata may sometimes be of significance as regards the moisture supply of the soils; the junction of the Upper and the Middle Chalk on the dip-slope is often marked by locally moister-than-normal conditions, whereas the reverse may be observed where this junction occurs on the scarp.

Apart from this effect, which may also occur due to a less permeable stratum in the Chalk, the distinction between dip slopes and scarps will usually be a question of relief and consequent differences in the depth of soil. The Chalk formations as far north as the Wash have at one time been covered by Tertiary marine deposits, and the remnants of these are important soil parent materials. The Yorkshire Wolds on the other hand are free of such deposits. The Chalk areas south of the Thames, which were not reached by the Pleistocene ice sheets, have no glacial tills. There are however extensive areas of glacial tills in East Anglia and parts of Lincolnshire. The Yorkshire Wolds are extremely free from glacial deposits.

Taking into account also very superficial deposits such as the loess, there is a rather complex series of soil parent materials overlying the chalk, though the deeper deposits do not come within the scope of this report.

In considering the soils of the downlands, a clear distinction should always be made between those which have developed from chalk itself as the parent material, and those which owe their origin to some superficial material which may be partly or wholly foreign to the underlying chalk. The distinction is easy enough to make at the extremes, but is rather more difficult to maintain where the deposits are quite shallow. The type soil derived directly from the Chalk is the rendzina which is usually a shallow soil without marked horizons, dark in colour due to incorporated humus, of loamy texture with well marked crumb structure. Particles of chalk are plentiful throughout the profile, becoming larger in size downwards as the fissured or shattered surface of the chalk is approached. The whole profile may be contained in a depth of 10 inches. Flints are often present in the soil, particularly where it has derived from the Upper Chalk. Some of the rendzinas in the Yorkshire Wolds are particularly stoney. The important features of such soils are their shallowness, extreme permeability, and high free lime content.

True rendzinas are not in fact the commonest soil types on the downs and are normally to be found only on steep slopes or sharp ridges. The evolution of rendzinas through the intermediate condition known as rendziniform soils, to brown earths and sometimes even further, to podsols, has been described by many authors. A particularly valuable account is that of Duchaufour (1950). It will suffice to note here that the process is essentially the progressive leaching of calcium carbonate from the profile, the humus derived from vegetative litter playing an important role.

In England, however, it does not seem that this process has proceeded far. Avery (1958) in a study of beechwood soils in the Chilterns, found that most cases of soil acidity were related to the nature of superficial deposits, rather than to soil evolution *in situ*. Nor does he suggest that chalk soils have evolved much faster under beech than under grassland. Perrin (1955) gives an estimate of 3 cm.—7 cm. for the depth of soil derived directly from chalk since the end of the Pleistocene, assuming no deposition of erosion. Calcareous drift materials (such as the Chalky Boulder Till of East Anglia) have become decalcified at much faster rates; however, it seems that foresters need not expect to see much deepening of the profile due to a single rotation on chalk!

Fortunately, however, true rendzinas are not by any means general and the soils overlying the Chalk are often derived from (or at least modified by) various superficial deposits. In the southern Chalk districts the most important of these is the well known Clay-with-flints. It varies greatly in depth from a foot or two to 20 feet or even more. Clay-with-flints occurs frequently as a cap on flat topped downs, and may cover extensive areas of less elevated chalk country. It has often been eroded from the steeper hill-sides. The Clay-with-flints is now considered to derive from the Tertiary Reading Beds, which have been very much weathered in the late Tertiary, and mixed with products of the Chalk

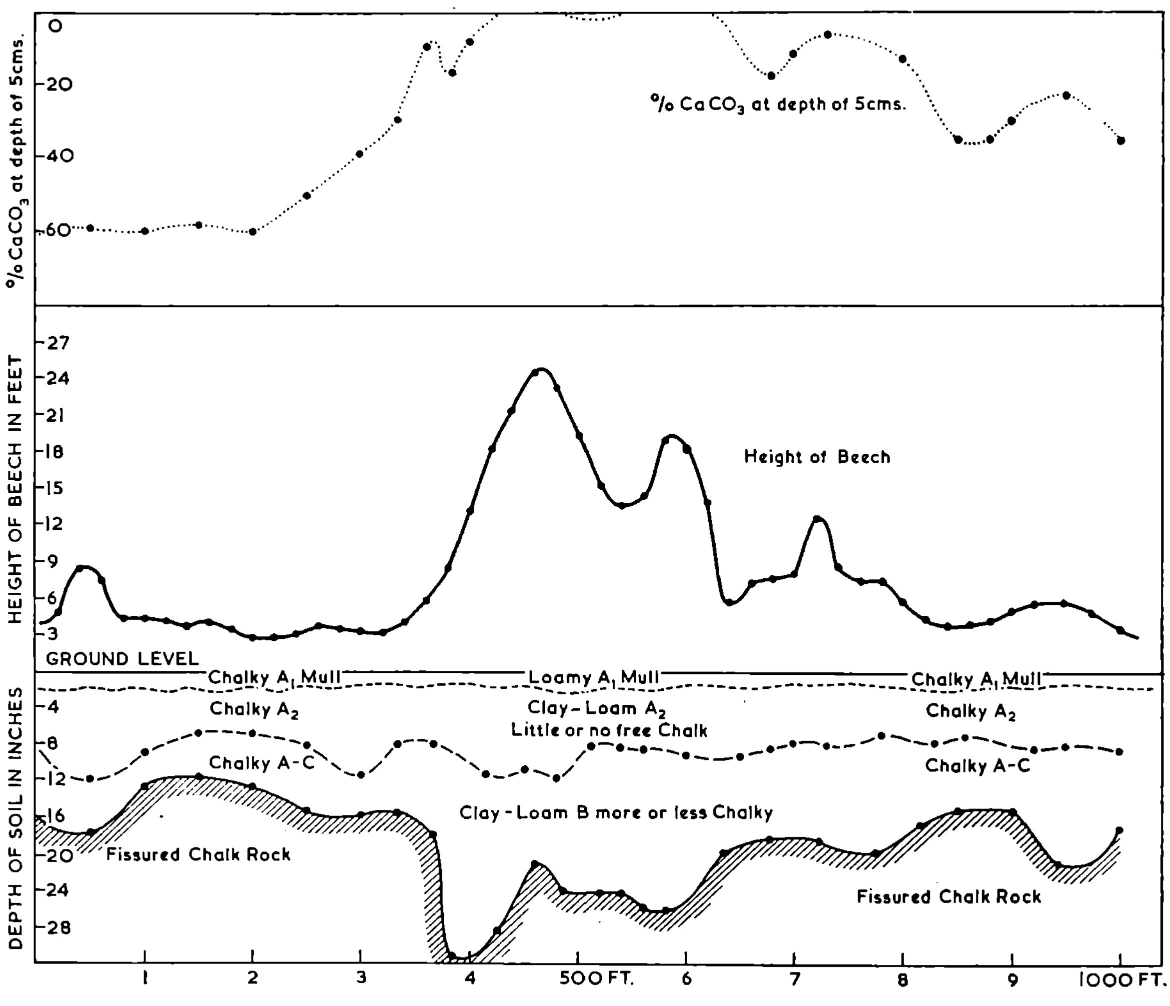

Fig. 2. Crawley Down, Hants. Height growth of beech and soil characteristics.

itself by the action of melting snow and ice during the Pleistocene galciations. Soils derived from the Clay-with-flints are usually loams or sandy clays, with many flint nodules or broken flints. They contain little or no free lime, and are usually somewhat acid in reaction. They are also much moister and more retentive than chalk-derived soils.

On chalk downs, the presence of Clay-with-flints is the most important modifying factor. It has a great bearing on the choice of species, and on the rate of establishment of plantations. This is well illustrated by a study conducted by D. F. Fourt at Crawley Forest, where the growth of beech in a 24-year-old plantation was measured over a transect some 1,000 ft. long, cutting across a Clay-with-flints cap on a small down mainly occupied by thin rendzina soils. The corresponding soil characteristics at each sampling point were also studied. Fig. 2 shows the main features of this transect, and it will be seen how closely the development of the beech is related to the soil type. This is a stage of growth where such an effect is seen at its clearest, since the beech on the thinner soils are still struggling against the competition of the downland sward, whereas on the deeper soil canopy has formed and the grasses have been suppressed. At a later stage, the difference in growth rates of the beech would not be so obvious.

Another material which is of some significance is the relatively thin deposit of wind-transported soil known as loess. This is now thought to occur very commonly over chalk downlands, lying as a fine layer of acid material over the chalk itself, on Clay-with-flints, or mixed in the surface layers. The interesting condition described by Tansley (1939) as 'Chalk Heath', where lime-hating plants such as *Calluna vulgaris* may be found growing in association with deeper rooting lime-lovers such as *Poterium sanguisorba*, may be due to a thin deposit of loess over the chalk. (Perrin 1955).

A further soil type of importance derives from the Coombe Deposits, which are the products of chalk itself and overlying deposits moved down the hillsides in a sludgy fashion by snow and ice meltwaters. Soils of this origin are usually light to medium loams and may be deep. This can be deceptive, since although the Chalk may be three feet or more below the surface, the soils may contain free lime throughout. Instances of lime-induced chlorosis have occurred in conifers planted on such soils in the belief that the free rooting depth over the Chalk was the most important factor. Soils derived from the Coombe Deposits may however have lost their free lime to some depth, in which case they may provide very suitable conditions for conifers. They certainly represent some of the best conditions for beech in the downlands. Coombe Deposits are chiefly found on gentle south, east and west facing slopes and in the dry valleys.

Coombe Deposits which have lost most of their fine material by the action of water are known as Valley Gravels, and deposits of this kind are often of importance in the dry Chalk valleys. There are usually many angular flints in soils derived from Coombe Deposits; on the other hand, most of the flints in Clay-with-flints soils are rounded, a useful means of distinction, though broken flints may sometimes be found on the surface.

At the foot of slopes and in very dry valleys there will often be found quite recent deposits of soil washed down from the upper slopes. These washdown soils may be difficult to distinguish from soils derived from Coombe Deposits. The most recent washdown soils are the result of erosion from cultivation of the downs in historic times, and often contain high proportions of very finely powdered chalk. These are very unpleasant materials and are extremely likely to give rise to chlorotic symptoms in young trees.

It may be helpful to show diagrammatically where these various soil forming deposits are to be found in relation to chalk downland topographical features. The sketches in Figure 3 are due to D. F. Fourt. They apply only to unglaciated chalk country.

The above brief descriptions may well suggest the danger of generalising about chalk downland soils. A further complication arises from the past history of cultivations. Ploughing, on the thinner soils, increases the amount of chalk in the upper profile, and this effect is very long lasting. Hence on certain downlands there exist important differences between sites which have been at some time past under the plough, and others nearby with fundamentally similar soils on which there are no signs of cultivation. When making preliminary studies of downland soils, the forester will do well to add an acid bottle to his equipment.

Fertility of Chalk Soils

For the forester an important question is whether or no the level of major nutrients present in the soil is likely to present a limitation to the establishment of plantations. In Britain, only one element (phosphorus) is commonly applied in fertilizers at the time of planting, and a rather narrow definition of a fertile site for afforestation is one on which no critical or important response to phosphatic manures is obtained. Generally speaking, responses to phosphorus at the time of planting are not obtained in Britain where total phosphorus in the subsoil is in excess of 1,000 parts per million (the figure is very approximate) (Green and Wood, 1957). Chalk derived soils will usually have phosphorus in excess of

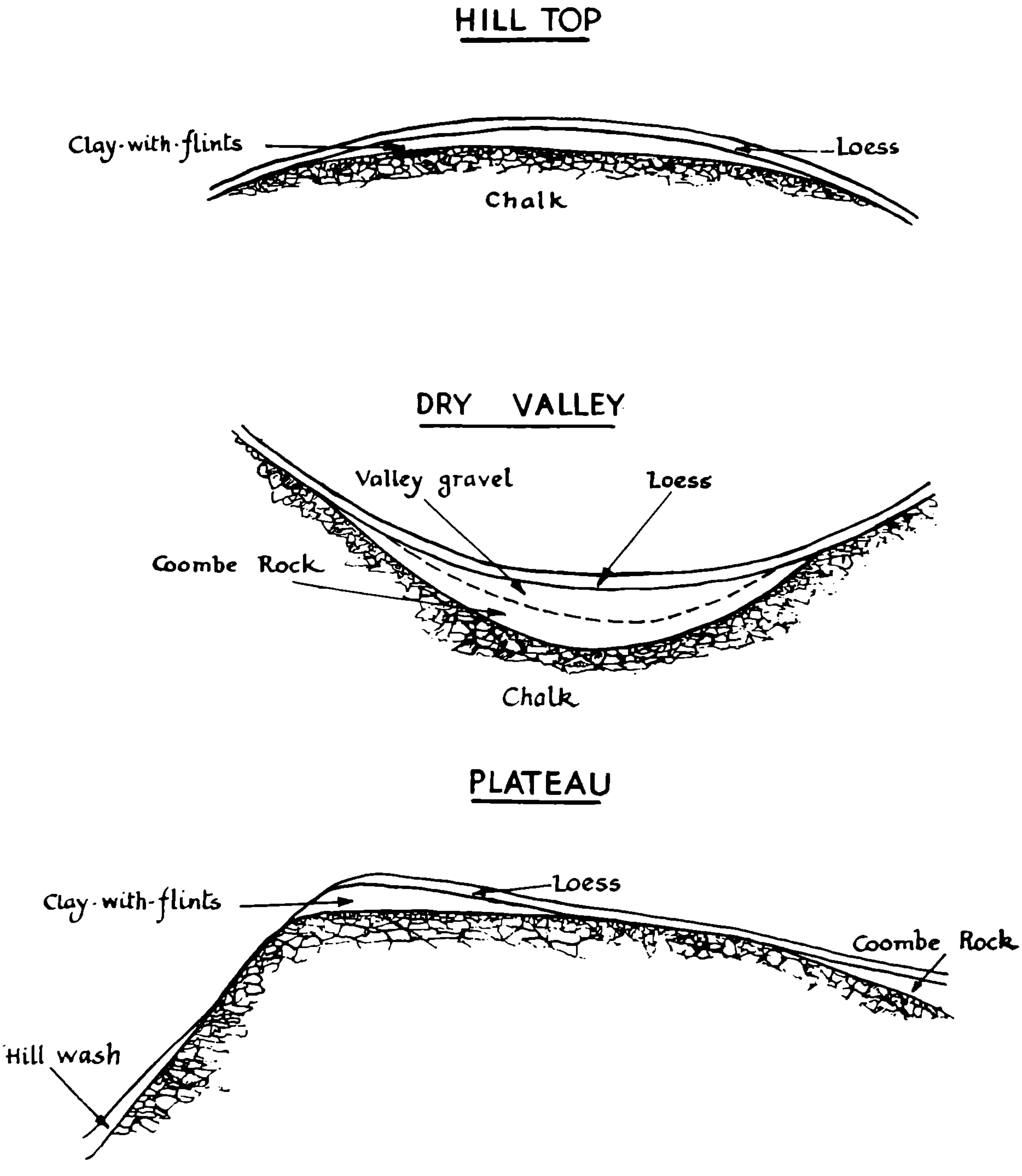

Fig. 3. The common superficial deposits in relation to topographic features.

this rather low figure, and what little experimentation has been done (see Chapter 4) does not suggest that the addition of phosphate at the time of planting is a useful measure.

Potassium is known to be deficient in chalk soils in agricultural terms, but it has never appeared to be an important deficiency in British soils in the establishment phase of plantations.

The most important nutritional features of chalk soils are related to their high lime content. Chlorotic symptoms, sometimes resulting in death of trees, have frequently been observed on lime-rich soils, more especially amongst conifers (Peace *in publ.*), but occasionally even in beech (Day 1946). Such troubles are grouped under the broad term 'lime-induced chlorosis', and generally attributed to the failure to take up, or make use of, certain minor elements in the presence of excess free lime. Iron and manganese are two elements which are frequently mentioned in this connection.

It is common to picture some direct antithesis to lime for certain trees, including most conifers, which are described as being intolerant of lime. If the root systems of Scots pine growing on chalk (one of the most prone of the conifers to chlorosis) be excavated, it is easily seen that any ideas of shy avoidance of the chalk are gross over-simplifications. The pine in fact roots vigorously into the shattered chalk, exploring every fissure, and the only limitation appears to be physical. (See Fig. 4). It is a little difficult to understand why trees which have been growing with their roots in intimate contact with the chalk for a number of years may become chlorotic and die in two or three seasons. However, from a recent survey of young pine plantations on the southern Chalk, it appears that chlorosis in pine is more closely related to the free lime content of the surface soil than to the depth to the chalk (Fourt 1959). A 'shallow' soil which is acid (e.g. one derived from some deposit now leached and decalcified) is less likely to give rise to chlorosis than a much deeper soil which has free lime throughout the profile; perhaps say, a downwash soil. Hence the importance of quite thin superficial deposits, such as the loess, and conversely, of past cultivations which may have redistributed chalk in the upper profile.

It has been observed that old woodlands on the chalk seem to provide conditions where a considerable range of conifers will grow, at least for a time, without trouble, whilst not shallower cultivated soils in the vicinity provide excellent examples of early chlorosis. No doubt this has something to do with the availability of certain elements in the thin acidified upper layers. It is also noticed that deaths from chlorosis are irregular and most prevalent in and early thicket stage in young plantations; the death rate may fall off markedly thereafter. This gives the appearance of shortage of supply of some element, rather than of a generally unfavourable condition, which would be expected to affect all trees at much the same rate.

It is also notable that edge trees in plantations have some advantage in this respect. Again, one has the impression that the behaviour of single conifer specimens in arboreta or gardens is not a very reliable criterion for judging the behaviour of the species in plantations on the same site. Certainly, very large specimens of Douglas fir have been observed on soils which one would hesitate to plant with that species pure.

While serious trouble from lime-induced chlorosis is most typical of the thicket stage plantation, newly established plants frequently appear chlorotic for several seasons. This is not usually fatal and is presumably caused by supply difficulties due to as yet inadequate root systems.

Vegetation

The typical vegetation of the downs today represents a particularly interesting example of sustained pressure by grazing animals. We do not have a clear picture of the conditions before man began to influence them, but something is known of the change of the floral composition since the end of the Pleistocene. Although the main ice sheets did not reach south of the Thames, it is thought that during the main glacial periods of the Pleistocene the downs can have supported little but a poor Arctic vegetation of dwarf willows, birches and such plants as *Dryas* (Godwin 1940). After the final retreat of the ice, post glacial changes of climate saw a forest of varying composition. Such species as oak, birch, hazel and pine appeared in the pre-Boreal. Beech is thought to have appeared later, during the sub-Boreal period which followed the long warm and moist Atlantic period.

The chalk regions of the south were almost certainly the first parts of England to be deforested. When the Romans arrived they found the chalk well populated and intensively cultivated, and it has been said that during the Romano-British period almost all the southern chalk was under the plough (Collingwood and Myres 1936). Towards the end of this period however a change from arable farming to sheep grazing was taking place, and the chalk was already assuming the sparsely populated character it bears to this day.

Young (1808) comments on the heavy stocks of sheep carried by the downland pastures, approximately one sheep to one and a half acres being a common figure. By the close of the nineteenth century sheep grazing had entered into a decline, and but for the rabbit, it is certain that downlands would have entered on the succession to forest conditions. The rabbit, introduced it is thought in Norman times, has been an important factor on the downs for several hundred years, finding well drained soil for its burrows and ample good grazing. The great diminution in its numbers (amounting locally, and temporarily, to extermination) due to the entry of myxomatosis in October 1953 has clearly demonstrated its role in the control of vegetation. This has been specially studied on chalk downland by Thomas (1957).

Chalk downland soils seem to have been marginal for agriculture for long periods, and cultivated only in periods of emergency or of high prices. Sometimes this return to arable farming has involved the clearance of chalk scrub. This was done on some scale in the last War. At the present time it seems that modern farming techniques have made it possible to maintain fertility and adequate production where there is some depth of soil and the terrain is not too hilly.

There are numerous excellent accounts of the flora of the downlands, and also of the successionary changes in the vegetation consequent upon the cessation of grazing. The studies of Watt (1924) are of special interest. Here only a brief outline will be given of the most important parts of the story from the forester's point of view. More detailed descriptions of vegetation on the chief experimental areas will be found in the Appendix.

Typical downland grass is a dense sward dominated by the Fescues (*Festuca ovina* and *rubra*), and containing a number of specialised herbs (calcicoles) which are most numerous on the steeper slopes where the soil is shallow and the grass mat is thinner. Wherever the soil over the chalk is deeper, as on Clay-with-flint caps or on downwash soils in the valleys, moister conditions allow a much less specialised vegetation; in particular a number of very much coarser grass species appear, such as *Dactylis glomerata*, *Arrhenatherum elatius*, *Holcus lanatus*, etc.

On certain downlands the grass *Bromus erectus* may be dominant in place of the Fescues (see Appendix). It appears to be less able to tolerate disturbance or hard grazing and such may reduce it from dominance to comparative rarity. Cultivation may have taken place in times of national emergency or of high agricultural prices, and after its cessation there is likely to be a more mixed grass/herb vegetation with a less dense sward than is usual after sustained grazing. The immediate effects of inclosure and the removal of the rabbit is to intensify the density of the grass sward, a change which is adverse to afforestation. This is not nearly so apparent on steep slopes with shallow soils, which can only support a rather sparse vegetation. With continued absence of grazing, or with greatly diminished grazing pressure, various woody species begin to make their appearance. The steepest escarpment slopes, with thin, dry soils, supporting only a sparse flora of calcicoles, are only slowly colonised by juniper and by yew. These are the most difficult conditions. Elsewhere, on rather deeper soils, a considerable variety of woody species can make headway. Hawthorn (*Crataegus* spp.) is the most important pioneer, and with it will be found wild roses (*Rosa* spp.), dogwood (*Cornus sanguinea*), blackthorn, privet, buckthorn, spindle, wayfaring tree (*Viburnum lantana*), travellers' joy (*Clematis vitalba*), elder and bramble, amongst others. The role of species with hard-seeded fruits attractive to birds is particularly important in the early stages.

Deserted rabbit warrens often provide favourable conditions for the commencement of the succession to woodland. Elder (*Sambucus nigra*) is a common pioneer associated with warrens. (See Plates 1 and 2).

The later stages of the succession from scrub to forest conditions depend on the moisture of the site in the first place, but are also no doubt much influenced by fortuitous circumstances such as the adjacency and nature of seed source. Oak and ash frequently invade the chalk scrub before beech, and on the deeper moister downland soils will hold their ground for a very considerable period.

Beech rarely appears as a pioneer species on downland and generally some shelter from woodland or scrub is required before beech seedlings can establish themselves. Undoubtedly part of the role of scrub lies in protection from grazing, but where this has been eliminated, beech seedlings are still at a disadvantage owing to the rather severe microclimate to be found in the open on grassy sites, and the competition from the sward in times of drought.

Successful establishment of beech on chalk downland will not usually be achieved without the application of some at least of the principles to be learned from the observation of the natural succession.

Plate 1. Rabbit warrens marked by elder scrub, before afforestation began, Friston Forest.

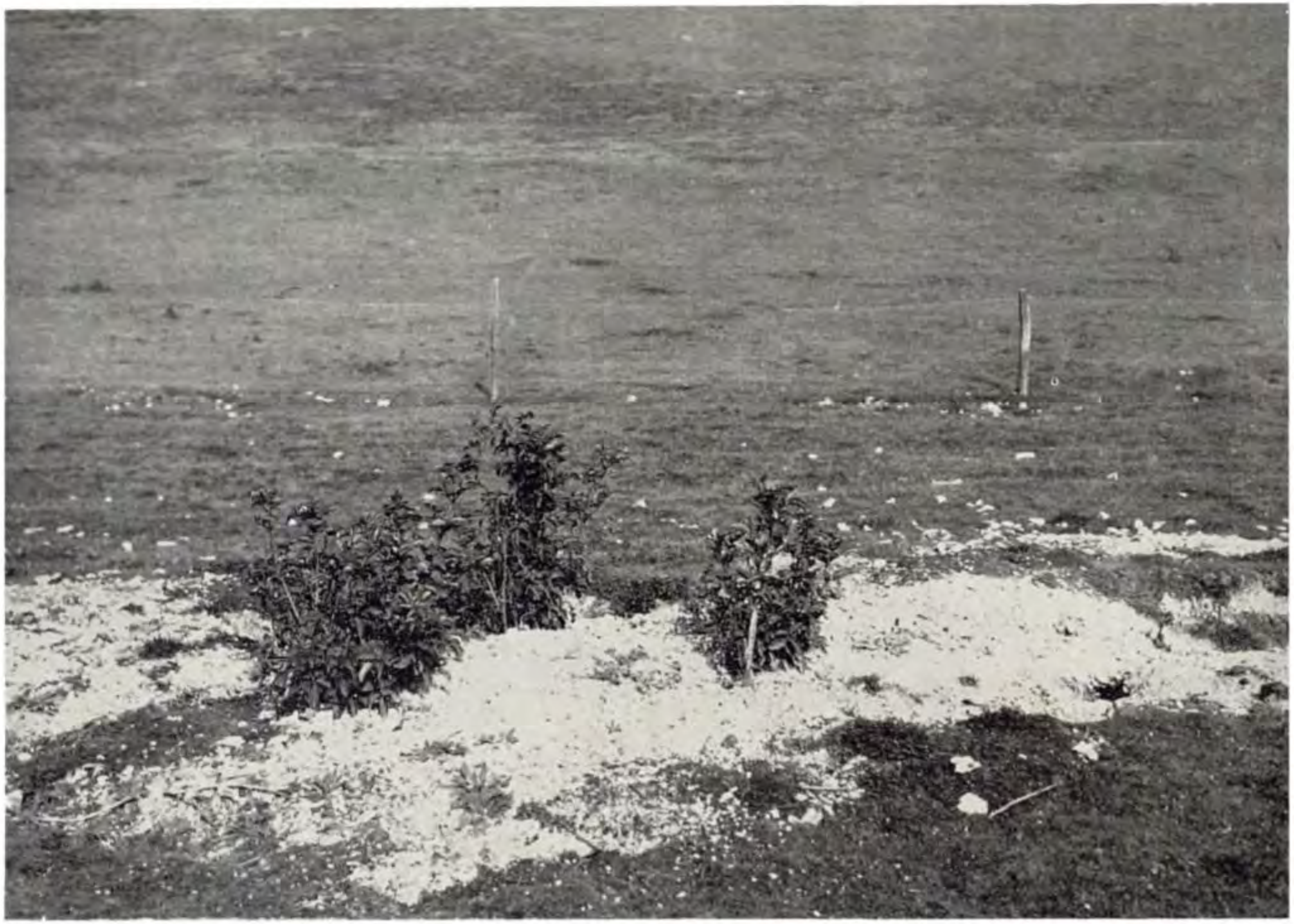

Plate 2. Elder growing on bare chalk turned out by rabbits prior to afforestation, Friston Forest.

Plate 3. Beech growing well on old rabbit warrens, aged 10 years, Friston Forest, 1938.

Plate 4. Experimental plot at Friston Forest, with vegetation hoed well away from beech, aged 11 years. Taken in 1938.

Plate 5. Monterey Cypress, *Cupressus macrocarpa*, transplants. Left to right: three times prelifted, twice prelifted, once prelifted and not prelifted. All aged 2 years (1 + 1).

Plate 6. Beech, aged 10 years, blasted by salt winds, Friston, 1938.

Plate 7. Beech, aged 10 years, protected by Scots pine, also aged 10 years, Friston, 1938.

Plate 8. European larch, aged 10 years, blasted by salt winds, Friston, 1938.

Plate 9. Ash, aged 10 years, checked by repeated frosting, Friston, 1938.

Plate 10. Scots pine dying at an age of 20 years on the chalk at War Down, Queen Elizabeth Forest, 1951.

Plate 11. Beech, aged 13 years, following a birch nurse crop. Friston, 1954.

Plate 12. Beech, aged 9 years, a gap in 10-year-old Corsican pine. Friston, 1954.

Plate 13. Beech, aged 9 years, introduced into Scots pine aged 10 years. War Down, Queen Elizabeth Forest, 1951.

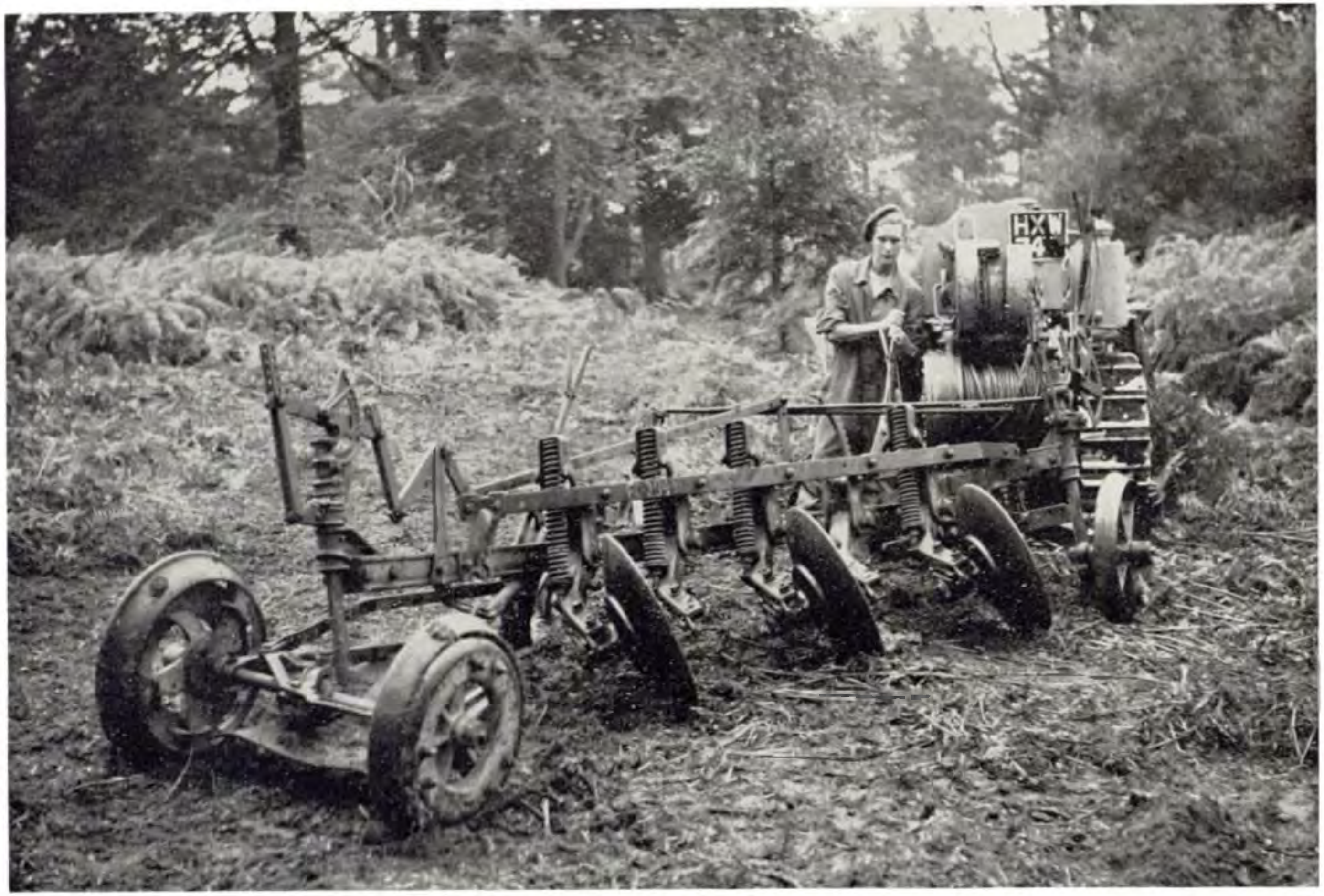

Plate 14. Sunshine "stump jump" plough used experimentally in 1951.

Plate 15. An example of Sunshine "stump jump" ploughing at Marden Forest, 1951.

Plate 16. Oregon alder, *Alnus rubra*, aged 11 years, at Holt Down, Queen Elizabeth Forest, 1941.

Chapter 3

HISTORICAL NOTES

In chalk downland country old plantations are not uncommon, and they sometimes form very conspicuous features of the landscape, as doubtless many of them were intended to be. It is of interest to enquire into the methods used to establish such plantations. Some of these have been established for shelter—and are thus in very exposed situations—equally, clumps and roundels planted for effect often occupy prominences which are very windswept indeed.

Nearly all these woods have beech as the dominant species, and often it is the only surviving species. But there is usually evidence that the plantations were established as mixtures with Scots pine, larch or sometimes other conifers. One sometimes finds a ditch and bank, often with the remains of a hedge, surrounding old plantations. A small 'roundel' in an exposed situation would derive considerable protection in this way during the establishment phase. No doubt some of these plantations were established with special care. There is a strong tradition to this effect concerning one of the most famous of them, Chanctonbury Ring in Sussex; it is said that the planter, Charles Goring, then a lad of sixteen years old, actually carried water for the plants to the top of the down 780 ft. high.

If one consults the older English forest literature, i.e. of the first decade of the nineteenth century or earlier, one is sure to be impressed by the emphasis placed on initial cultivation in the formation of plantations on various types of ground. It appears to have been widely accepted that it was highly desirable to plant into land cultivated to much the same standard as required for an agricultural crop, and indeed the practice of preceding a plantation with a farm crop of one sort or another is commonly recommended. The tending of newly planted woods also seems to have been very intensive, and carried well beyond the mere cutting back of weed growth. The hoe is often mentioned, and on the better soils, agricultural cropping might be carried on between the rows of young trees for a few seasons.

There is of course a difference between what is actually done and what is written in the contemporary text books, but allowing for the enthusiasm of some of the authors it seems safe to assume that in the late eighteenth and early nineteenth century (an active period in English forestry) the establishment of a plantation was frequently, if not generally, an intensive operation.

Direct references to the chalk are not common in the literature of this period. It is of interest, for example, that the chapters on Woodlands in the *General Views of Agriculture* for the counties of Hampshire, Dorset and Sussex (Published by the Board of Agriculture during the years 1808–1813) make little or no mention of planting on chalk, though they record considerable activity on various other types of land. On the other hand, the Yorkshire Wolds appear to have been the scene of some very notable efforts at this period, and these will be mentioned later.

Of the earlier writers Pontey (1808) is the most specific on the subject of planting on chalk. He does not agree entirely with some of his contemporaries about the necessity for the most drastic preparation, such as trenching with the spade. He comments that most planting sites, not specifically chalk ones, are 'too steep, stoney, bushy or heathy, to admit of the sort of preparation alluded to, or otherwise too sandy to need it'. He is obviously familiar with the difficulties of chalk downland planting, and the following remarks might well have been made 150 years later concerning Friston or Queen Elizabeth forests:—'The losses which have followed planting such of them as have been long under grass, show clearly the difficulty of the business. Generally these losses have happened from the circumstances of drought and exposure and therefore means should be used to guard against both'. Complete ploughing, followed if possible by a wheat crop, was the first part of Pontey's answer. Failing a wheat crop, he liked to leave the ploughed ground a full season for consolidation before planting. He did not recommend a very large plant, his stock seems to have been about 3–4 years old, once transplanted. He advocated the placing of upturned turves round about the newly planted tree for shelter and as a measure against drought. The species he liked to plant on the chalk were larch, Scots pine, beech, birch and sycamore;

the birch and Scots pine being planted specifically for shelter—'where most bleak, a considerable proportion of the Scotch firs'. Where losses had occurred and ploughing being no longer practicable inside the plantation, he recommended imitating the effects of ploughing by reversing large turves into the holes from which they were cut, and planting thereon after an interval for consolidation. (This interesting trick was in fact repeated at Queen Elizabeth forest in 1932 with excellent results). It is clear that Pontey had a good grasp of the problem, and had practical measures for its solution.

As examples of chalk planting in his day he specially commends the plantations of the Earl of Chichester at Stanmer in Sussex and of the Sykes family at Sledmere on the Yorkshire Wolds. The latter seems to have been a very considerable project. Strickland (1812) credits the Sykes with the establishment of about 2,000 acres of plantations on the Wolds, and other estates on the Wolds also seem to have been active at this period. In this area the use of Scots pine as a nurse seems to have been general, but its defects on calcareous soils were recognised. Strickland comments 'On the Wolds, the Scotch fir shoots vigorously for a few years . . . After . . . about 20 years however it may die without any apparent cause'.

The methods adopted at Sledmere differed in one very important respect from those recommended by Pontey. Ploughing, though it had been tried, was not considered a success, and better survival was obtained by pit planting with the turf inverted at the bottom of the pit. (Pontey's 'second best' method, in fact). Extremely close spacing was adopted, the aim being to secure some 5,000 live trees per acre three years after planting. Some 3,000 of these were conifers, European larch being much planted in addition to Scots pine. Beech was the principal hardwood, but ash and elm are also mentioned. Conifers were regarded as nurses and sources of early revenue, being all removed in stages by the thirtieth year.

Strickland quotes Sir Christopher Sykes' own words on this—'I always belt round my plantations with Scots fir, and intermingle them throughout, but I never make a plantation solely of the Pinus tribe (sic, conifers generally) as I conceive them to be too temporary'. Sir Christopher Sykes did not believe in intimate mixtures, but preferred to plant the various species in small groups of twenty to thirty trees. This he found obviated the trouble of the rapidly growing nurse species damaging the hardwoods at an early stage.

On planting technique, another interesting early reference (Anon 1832) is to a plough as designed by a Berkshire landowner (Charles Fyske Palmer). This consisted of a large triangular base plate with sharp edges. It had double mould boards, and skinned off a thin turf which was thrown to either side. It was developed specially for preparation for planting on 'grassy heaths', and sounds as if it might have been quite a useful appliance.

In more recent times there have been a number of published accounts of planting on chalk downlands, usually concerned with experiences on particular estates. Pope (1916) gives an interesting account of plantations at Wrackleford on the Dorset Downs, made from 1890 onwards. 'Permanent crop(s) of hardwoods' were the objectives, and high proportions of conifers were planted as nurses in the first place, apparently two rows of conifer to one of hardwood. A considerable variety of species was used; European and Japanese larches, Scots and Austrian pines, Norway spruce, beech, oak, Sweet chestnut, ash and sycamore etc. This seems an unnecessarily extended list, but it is noticeable that difficult sites sometimes serve as a challenge to attempt half a dozen more species than are necessary for the purpose. The more recent literature has many references to the behaviour of various species.

Lawson (1916) (in fact in the same number of the *Quarterly Journal of Forestry*) has an account of planting on the South Downs in which he reports favourably on a number of plantations formed about the turn of the century or a few years later. Most of these contained a number of conifer species in mixture with beech, and Douglas fir seems to have been in vogue at this time. He is not specific about the methods of establishment, or the arrangement of mixtures. The editorial (Anon 1916) in this issue of the journal referred to above mentions a number of small plantations on extremely exposed downs in Berkshire and Sussex. The well known beeches at Chanctonbury Ring are referred to as an example of the good growth possible on such exposed downland sites.

Shelter has always been a common object in forming plantations on chalk downlands, and one of the first truly experimental plantations of which we have records was in connection with the improvement of agricultural land. This was Sir William Somerville's use of *Cupressus macrocarpa* in a shelter belt at Poverty Bottom, near Seaford, Sussex (Somerville 1917/18). Somerville's very successful plantation has recently been described by Macdonald, Fourt and Christie (1954). Mainly due to the notorious difficulties in establishing it, the species has not been at all widely planted since Somerville's time.

Chalk afforestation has not attracted a very extensive literature. Many of the references to planting on chalk are of very slight value, frequently owing to the failure to define the environment. Enough however has been quoted to show that the main problems of establishing woodland on chalk downland were recognised many years ago, as were practical techniques to resolve the difficulties. In fact this is not one of the divisions of English forestry in which one can point to sustained progress, or notable advances. On reading Pontey one feels (in the parlance of the cinema-goer) that 'this is where we came in'.

Chapter 4

PLANTING TECHNIQUES, WITH SPECIAL REFERENCE TO BEECH

In the previous chapter, some mention was made of ancient practices in planting on Chalk. The methods adopted at such forests as Friston and Queen Elizabeth in the late 1920's appear at first sight to represent a recession rather than an advance, but the big difference in labour costs had put the emphasis on lessening the cost of establishment rather than on discovering ideal, but impracticably expensive, techniques. Most of the experimental work carried out since the first World War has been centred on the two forests mentioned above, and the conditions are described in some detail in the Appendix. The environment at Friston is the more difficult for afforestation, especially with regard to exposure, since the close proximity to the coast adds salt spray to the normal effects of wind.

These experiments were largely undertaken during the years 1927 to 1934, and since this period there has taken place the main development of ploughs for the preparation of various types of ground, for drainage, cultivation or weed suppression according to the requirements of the situation. Ploughing has extended its benefits to the chalk downlands, but since these sites do not bulk very large in the Forestry Commission's planting programmes, ploughs for chalk downlands have not been made a subject for much special development, and the machines employed have usually been those found most suitable on mountain grasslands and the less difficult types of heath. Ploughing will be returned to later, after considering some of the earlier techniques, certain of which throw light on the basic requirements for mechanical cultivation.

HAND METHODS OF SITE PREPARATION AND PLANTING

Seventeen experiments on this general topic were carried out at Queen Elizabeth and Friston forests, and the following methods figure in them:

1. Notch planting into the undisturbed vegetation surface.
2. *Schrägpflanzung*—planting on the slant into the natural undisturbed surface so deeply that only the tip of the shoot remains above ground.
3. Notch planting into screefed patches.
4. Notch plantings into continuous screefed strips 18 in. wide.
5. Notch planting into inverted turf patches 18 in. square.
6. Notch planting in groups into dug-over squares 6 ft. × 6 ft.
7. Pit planting with and without the addition of humus in various ways.
8. Fork planting—a method evolved to suit the stony conditions in parts of Friston Forest, but equally applicable elsewhere.

The experiments do not form a connected series and hence comparison between some of the methods is not possible, save in the most general terms.

Notch Planting

Notch planting into the undisturbed sward is the cheapest hand technique. It is a method used on many different types of ground, the technique varying; but the common element is the provision of a vertical cut by an ordinary garden spade or some special narrow bladed planting spade (Mansfield and Schlich spades are familiar patterns) into which the roots of the plant are inserted. Normally there is little cultivation effect. In an experiment with beech at Queen Elizabeth Forest laid down in 1933, notching into the undisturbed surface (a dense *Festuca* sward) compared very unfavourably with notch planting into 'screefed' patches, losses with the former method totalling 48% after four seasons compared with 4% for the latter. Screefing implies the local removal of sward or other vegetation with a mattock. It is of interest that in this case the respective figures for losses at the end of the first season were 14% and 3%, illustrating the point that on chalk downland it is undesirable to judge the success of a method of planting by losses in the first season, since the subsequent development of the sward may bring about fatalities, let alone checked growth, for several more seasons. At Friston, on a less competitive sward, losses with notch planting of beech into the undisturbed surface totalled 27%, five seasons after planting, as compared with 5% for notching into screefed patches. Whilst trees may on occasion 'get away' without some form of surface preparation, notching into the undisturbed surface is a generally unsatisfactory method likely to be attended by heavy losses and slow growth.

Schrägpflanzung is a German technique which may be regarded as a variant of notching. Plants are inserted on the slant so deeply that only the tip remains above the surface. The method is said to have merits on dry sites; however when compared with notching into screefed patches in two experiments at Queen Elizabeth Forest in 1933, losses averaged 66% against 18% for the latter method. It is difficult to see why any method which makes no effort to control the grass sward should succeed.

Screefing

The screefed patch may be regarded as a standard minimum preparatory measure, and notching to screefed patches was the general method of planting employed in the Forestry Commission's early plantations at Friston (Aston 1933) and Queen Elizabeth Forests. Several variants of the screefed patch have been tried. Continuous screefed bands, a logical extension of the patch, yielded somewhat unexpectedly no further advantage, though it is felt that the comparison may have suffered from the more drastic removal of top soil involved in making the bands. It is interesting to note here that in Queen Elizabeth Forest many small areas had been worked for lawn turf before the land was acquired for afforestation. This has proved very detrimental, and the ill-effects can still be seen over twenty-five years later. The removal of the top soil, either altogether or merely from the neighbourhood of the roots, is extremely likely to produce chlorotic symptoms, especially on conifers, but occasionally even on beech.

Another early experiment conducted at Queen Elizabeth Forest in 1932 extended local vegetation control to the complete screefing of a patch some 8 ft. × 6 ft. in area, such patches being centred 15 ft. apart, and planted with twenty-one beech at 2 ft. spacing to form tight groups. (An example of the 'Anderson Group' (Anderson 1930)). While early canopy closure was obtained, growth proved disappointing, again it is thought due to the removal of over much top soil.

Hand Cultivation

Screefing is not a cultivation, and any benefits it confers are plainly due to the reduction of vegetation competition, principally no doubt for moisture. Some slight degree of cultivation inside the screefed patch has sometimes been provided by the use of the pick end of the mattock (Aston 1933). At Friston, by 1930 Aston (ibid) had adopted the garden fork as a planting tool, using this to loosen up the mattock screefed patch before inserting the plant. Experience at Friston indicated that this degree of cultivation considerably reduced planting losses. This method was especially suited to Friston because of the flinty soils there.

This, and similar methods, are sometimes described as 'semi-pit' planting, and the distinction from pit-planting proper is a matter of degree rather than of kind. Pit planting usually implies deeper cultivation, facilitated by the removal of the top soil, which is subsequently replaced in the act of planting. It is of course particularly applicable to the larger type of plant, but with normal sized planting stock the experience at Queen Elizabeth and Friston forests has been that survival rates have not been notably higher than those achieved by less expensive methods, e.g. screefing followed by notching or semi-pit planting. Nor have early growth rates proved impressive. It seems probable that this has been due to the failure to secure adequate consolidation.

Inverted Turves

An experiment (not concerned with methods of planting) laid down at Queen Elizabeth Forest in 1932, was established by an unusual method. Deeply cut turves some 18 in. square were inverted in the holes from which they were cut and the plants notched therein. The survival rates of both beech and larch in this plantation were excellent, exceeding 60%. It will be recalled (Chapter 2) that Pontey advocated a similar planting method in 1808.

Cultivation and Incorporation of Litter

The late Lord Robinson initiated an interesting experiment at Queen Elizabeth Forest in 1947 in an attempt to throw some light on the difference between downland and woodland chalk soils in respect of the difficulty of establishing beech. He compared six treatments involving various combinations of cultivation and the addition of beech litter. The treatments and the results five seasons after planting are summarised in Table 2 (overleaf).

Cultivation significantly reduced planting losses, and the addition of beech litter as a mulch also seems to have been of some benefit in this respect, even in the absence of cultivation; but the best survival by far was obtained by the incorporation of litter throughout the cultivated volume. Differences in height were not very striking, but significant gains were obtained from combinations of cultivation and the incorporation of litter either at the bottom or throughout the pit. It is difficult to interpret these results in practical terms. The marked superiority of the cultivation and incorporated litter treatment presumably implies good rooting conditions and some improvement in moisture retention. The results certainly suggest that cultivations ought not to remove what organic matter there is from the immediate

TABLE 2: SURVIVAL AND GROWTH OF BEECH AFTER FIVE SEASONS AT QUEEN ELIZABETH FOREST—EXPT. 45, 1947

	Treatments	*Deaths*	*Mean Height (inches)*
A.	No cultivation, notch planting to screefed patch	67.5%	23.2
F.	No cultivation, notch planting to screefed patch plus ⅓ cu. ft. of beech litter applied to surface as a mulch	49.2%	20.2
B.	Cultivation of one cubic foot of soil	40.0%	25.5
D.	Cultivation of one cubic foot of soil plus ⅓ cu. ft. of beech litter worked throughout soil	16.7%	31.0
C.	Cultivation of one cubic foot of soil plus ⅓ cu. ft. of beech litter as layer at base of pit	29.2%	30.6
E.	Cultivation of one cubic foot of soil plus ⅓ cu. ft. of beech litter applied to surface as a mulch	33.3%	24.5
	Differences for significance: . .	*5%* : 21.1% *1%* : 28.6%	4.6 6.1

rooting environment, but there are obvious mechanical difficulties in avoiding this.

Summary of Hand Methods

To summarise these trials and experiences with various 'hand' methods of preparation and planting:

(i) It is plainly indicated that some measure of cultivation beyond that required merely to insert a plant into the ground is very desirable, though the actual amount of cultivation does not seem to be a very critical factor. Probably one of the main advantages of cultivation is that the planter is able to get the roots well down, not bunched up close to the surface waiting to dry out.

(ii) Even to secure adequate survival, it is usually necessary to reduce sward competition for the first few seasons growth.

(iii) The removal of top soil from the immediate rooting environment is likely to be deleterious to survival and early growth.

MECHANICAL CULTIVATION AND CHEMICAL METHODS OF SWARD CONTROL

On certain wasteland types, notably moorland and heathland, hand methods of preparation and planting clearly antedate ploughing. This is hardly the case on the chalk, for the simple reason that many downland sites have been under the plough in peak periods of arable farming; it has always been obvious that if land can be ploughed for agriculture with the implements available at any time, it can equally be ploughed as a preparatory measure for planting. Hence at all periods some ploughing seems to have been done, though not till the entry of the crawler tractor has it been at all easy to cultivate the steeper slopes. There has however been little direct experimental investigation of methods of ploughing on chalk, but rather a gradual collection of experiences which are difficult to compare since they occur in different seasons and on different sites.

Shallow Single Furrow Ploughing

Some ploughing was done in the first season's work at Friston forest in 1927. A horse-drawn Ransome single furrow plough was used, and the furrows were spread 4½ft. apart. This type of ploughing continued at Friston till about 1932, no very great acreage being attempted in any single year. It was usually very shallow, the furrows being only about 4 inches deep. The bottom of the furrow was the preferred planting position, and experiments at Friston confirmed that, for survival, this position was superior to the top of the ridge; the former showing losses of some 6% against 18% for the latter. Shallow single furrow ploughing is not however a good method of preparation, since (without a subsoiler) the bottom of the furrow is too compacted for ease of planting, also much of the top soil has been removed from the immediate environment of the plant. Nor is the control of sward very effective. Complete ploughing (after the fashion of the ancients) does not seem to have been favoured in the early years at Friston, partly no doubt for reasons of economy, but also perhaps because the benefits of planting in the bottom of the furrow were ascribed largely to shelter. Although there is little direct evidence, there is no doubt that even shallow single furrow ploughing is of some value for survival and subsequent growth, as compared with planting to the undisturbed surface. An unofficial experiment (unfortunately unreplicated) carried out at Queen Elizabeth Forest in 1950 compared the survival and growth of beech on single furrow ploughing five inches deep with that from planting into the undisturbed surface; the results are summarised below:—

Recent Developments

The most profitable developments have occurred since about 1935, when more powerful tractors (especially crawlers) became available. Two main lines appear to have been followed—on the one hand complete ploughing, on the other, double-throw ploughing with subsoiling. The methods have not been strictly compared on any site, but while no doubt there are conditions to which either method could be applied, they are not fully interchangeable.

Complete Cultivation

Complete ploughing appears applicable to any type of chalk downland site provided that equipment used is suited to the depth of soil over the chalk. It is extremely important that where there is only a thin layer of acid material, the underlying chalk rubble is not brought to the surface. On very thin soils this limits cultivation to little more than surface working with discs. However, if it can be carried out, it is on the shallower soils that complete ploughing has the greatest advantages, since here any form of partial ploughing leaves a difficult choice of planting position; the ridge is likely to be too dry, and the furrow bottom may lack soil, or even have the chalk exposed. Various ploughs have been used. At Arundel in 1955 good results were obtained with a Fisher Humphries Bracre plough, drawn by an International T.D.9 crawler tractor. At Marden, complete ploughing was carried out on very thin soils in 1950/51 by a Sunshine Stump Jump plough, a multiple disc outfit designed for cultivating cleared scrub or forest land. (See Plates 14 and 15). The 'Forestry Commission R.L.R.' plough was also used for complete ploughing at Marden.

Consolidation is extremely important after complete ploughing, and disc ploughs give a particularly fluffy surface. It will have been noted that the old authorities (see Chapter 2) liked to leave the land a full season to settle before planting. We are however in a greater hurry, and consolidation is often obtained by running a crawler type tractor across the furrows. Sward control is probably more effective with a conventional mould-board plough than a disc, provided always the furrows are well turned, but in any case a single cultivation does not give any lasting freedom, and the surge of weed growth in the second and third years may be very alarming. The ancient practice of taking an agricultural crop off the land before planting was probably extremely sound, and no doubt gave much better control of sward. There is no doubt that it would be a great advantage were it possible to carry out fallow cultivations during the summer before planting.

Mechanical Planting

To digress, the reasonably homogeneous conditions often found on chalk downlands may provide the opportunity (rare in this country) to attempt mechanical planting. The Lowther planting machine was very successfully used at Harting Down, Queen Elizabeth Forest, in 1956. On previously fully ploughed land, with a team of three men, planting was carried out at a rate of 12,000 plants in eight hours, with satisfactory survival rates not significantly different from those obtained by hand planting. The James Tumbrel (Anon 1954), which has spuds on its wheels making planting holes as it is drawn across the ground, has also performed very successfully on ploughed chalk downland at Arundel forest.

Double Mouldboard Ploughs

Double mouldboard ploughs with subsoilers have been very successfully used at Brighstone Forest, Isle of Wight, and at Blandford Forest, Dorset. The model used has been an adaption of the Ransome 'C.C.C.' plough. This has a strong subsoiler bar, and a shallow working double mouldboard. It has been operated at five foot intervals, and inverts the turves to either side of an eighteen inch wide 'screef', down the middle of which is the cultivated trace of the subsoiler into which planting takes place. Provided

TABLE 3: SURVIVAL AND HEIGHT GROWTH OF BEECH AFTER TWO SEASONS AT QUEEN ELIZABETH FOREST

	Survival	*Height (inches)*
On plough	80%	34
Undisturbed surface ..	64%	20

(The planting position in this case was the *top* of the ridge).

TABLE 4: PLANTING LOSSES FOR DIFFERENT KINDS OF BEECH PLANTING STOCK AT QUEEN ELIZABETH FOREST

	First-year Seedlings	*One-year—One-year Transplants*
Expt. 1, 1930	49%	28%
„ 7, 1932	19%	14%
„ 12, 1933	30%	26%

the depth of soil over the chalk is adequate, the preparation is very favourable. It appears particularly applicable to chalk sites with flinty top soils, where cultivation is desirable to obtain a good take and ready establishment. There is quite good initial control of vegetation, though sward may be expected to return in force by the third season or earlier, following wet summers. It has, however, been observed that on many recently ploughed areas, the check associated with the return of the grasses is not nearly so serious as it used to be with the old methods of hand preparation, or shallow single-furrow ploughing. The provision of really good conditions for the first two seasons (at least) is critical. It is also of interest to observe the more even development of mixtures, notably Corsican pine/beech mixtures, on the more successful cultivations. The faster early growth of beech under these conditions will undoubtedly make for easier management of the crops from the thicket stage.

Subsoilers Only

At Friston in the last few seasons, cultivation has been carried out by subsoiler alone. Plants are inserted direct into the tine slit and the take has been very satisfactory. This method sacrifices sward control, but of course avoids bringing chalk to the surface.

Quite recently experiments have been carried out in Yorkshire with a 'Rooter', a set of extremely heavy subsoiling tines drawn by a crawler tractor. This seems to have given useful cultivation both on old woodland sites or bare downland.

Cultivations, however adequate, do not solve all the problems. There still remain the special difficulties associated with very thin soils on steep slopes—the most difficult conditions being found on southern aspects. It is very doubtful whether the thinnest soils are worth planting, and where they occur inside larger areas of better soils, they might well be left to natural succession with a little artificial assistance.

Chemical Sward Control

A recent development which shows considerable promise is the use of the herbicide delapon, which is selective against grasses. Experiments are proceeding with the substance on a number of types of ground (including the chalk) where grasses are a serious handicap in planting (Holmes 1961). The indications are that complete control of downland sward can be obtained by applications of 10–12 lb. commercial dalapon (74% acid) in the months of early summer or early autumn. The possibility of residual toxicity, which would affect the safe interval before planting could take place, is being looked into. It is not thought that this will be a serious hazard, since it is one of the interesting effects of dalapon that herbaceous and woody constituents of the flora rapidly colonise the sites where the grasses have been killed. The great attraction of such a method is that sward control is achieved without disturbance of the top soil, and this is of very real importance on the shallow soils, where any form of cultivation is likely to bring chalk to the surface. The cost of such treatment seems likely to be about £6 per acre, and this is by no means prohibitive, being roughly equivalent to the cost of single furrow ploughing, plus a single years weeding.

Dalapon might be of special value if used in conjunction with subsoiling, as practised at Friston.

Summary of Mechanical Cultivation and Chemical Sward Control

To summarise; successful mechanical cultivation should delay the return of grasses as long as possible and should also provide a good planting position. It should not bring chalk up into acid surface soil. These conditions are not compatible on the thinnest soils.

Single furrow ploughs without subsoiler have usually failed to give an adequate planting position. Subsoiling is very desirable where soils are impacted, and the double mould board plough with subsoiler has proved a useful method where there is some depth of soil over the chalk. Complete ploughing with conventional mould board ploughs or discs is a useful method where there is no lime-free soil to lose, consolidation is however very important. Without a season's fallow, no mechanical cultivation can do more than delay the return of the sward. Recent experiments suggest that dalapon may play

TABLE 5: GREY ALDER AND CUPRESSUS MACROCARPA: PLANTING LOSSES OF DIFFERENT KINDS OF STOCK

Losses.

	Cupressus macrocarpa *Friston Forest*	*Grey Alder* *Queen Elizabeth Forest*
1+0 Seedlings ..	90%	57%
2+0 „ ..	70%	11%
1+1 Transplants	17%	3%

a very useful role, possibly in conjunction with subsoil cultivation.

KIND OF PLANTING STOCK

Chalk downlands being exposed and rapidly drying sites, unsuitable (too small, too large or unbalanced) planting stock is at a special disadvantage. Experimentation has not been carried far enough to determine the ideal kind of stock, but comparisons of one-year beech seedlings with one-year, one-year transplants made at Queen Elizabeth forest in the early 1930's left little doubt of the superiority of the transplants:—

These results are in accord with general experience; it should however be borne in mind that site preparation and kind of stock interact. It may be possible to 'get away with' seedlings where preparation is particularly good. Two-year-old seedlings have frequently been planted with success. There is probably no critical difference between two-year, one-year transplants and one-year, one-year transplants.

Some experimental evidence exists for species other than beech. Comparisons of one-year seedlings, two-year seedlings, and one-year, one-year transplants were made for Grey alder at Queen Elizabeth Forest and for *Cupressus macrocarpa* at Friston.

Cupressus macrocarpa is a notoriously difficult subject to establish. It is of some interest in this context to draw attention to an experiment carried out with plants raised at Kennington Nursery and planted at Queen Elizabeth Forest in 1931/32, comparing the survival values of one-year 1-year transplants, lifted and heeled in at various dates in the nursery.

The October lift encouraged the development of a very bushy root system (see Plate 5). The excellent survival of October lifted plants might be explained by this, but later lifts also proved effective to some degree in reducing losses, without equally noticeable developments in the root system.

Provenance of Beech Seed

No evidence is available on provenance of beech with special application to chalk soils as against other soil types. Provenance experiments at Queen Elizabeth Forest are as yet too young to afford reliable information. Some of the best English beech happens to be found on the South Downs, but there is no reason to suspect that seed from good stands on, say, the Cotswolds is in any way inferior for chalk down afforestation. Since the second World War much attention has been paid to the origin of seed. Beech seed is now collected from a restricted number of stands of good form of growth, and it has been claimed by experienced foresters that young beech plantations now exhibit a much higher proportion of well formed stems. Since provenance

TABLE 6: CUPRESSUS MACROCARPA: PLANTING LOSSES OF ONE-YEAR, ONE-YEAR STOCK PRE-LIFTED AND HEELED-IN AT VARIOUS DATES. QUEEN ELIZABETH FOREST

Pre-lifted and Heeled-in				*Planted*	*Losses*
Three times pre-lifted	Oct.	Dec.	Feb. ..	April	12%
Twice pre-lifted	—	Dec.	Feb. ..	„	37%
Once pre-lifted	—	—	Feb. ..	„	53%
Not pre-lifted	—	—	—	„	78%

experiments show very considerable differences in the vigour and form of beech from various English sources, there is no reason to doubt that a useful improvement has been effected in recent years by careful selection of seed source. The inherent qualities of the planting stock have an obvious bearing on the establishment of plantations, since the larger the proportion of stems of good form, the fewer need to be planted merely to provide an adequate selection. Mixtures of beech with conifers, can, if the beech is reliable, have comparatively small proportions of beech; it must always be kept in mind however that on difficult sites such as chalk downlands, young beech is often slow starting and is at the hazard of the elements for a considerable time before canopy has formed, during which there is ample opportunity for the development of forks, twists and other deformations.

SEASON OF PLANTING

Many foresters are aware that autumn is, broadly speaking, a better planting period than spring. It may be very markedly so with certain species. Some useful evidence was collected for beech at Queen Elizabeth Forest in the three seasons 1938/39—1940/41. The plants used were one-year, one-year transplants and the method of planting was the standard notching to screefed patches.

The results of the three experiments are summarised in Table 7 below:—

The important trend common to the three experiments is the comparatively low percentage of failures for October planting. The order of losses throughout the experiments is very high, but by no means outside the general experience at the time these were laid down. Three seasons' work is insufficient evidence on which to base any general conclusions about season of planting, but experiments on other species in the south of England tend much in the same direction. October usually presents a combination of favourable circumstances; soil moisture and temperature, and atmospheric humidity, are usually very satisfactory; and root activity has not ceased.

SPACING IN PLANTATION

For some curious reason no experiments have been laid down in this country to enquire into the effects of spacing in pure plantations of beech, though much work of this kind has been done for other species. Today, the enquiry would be somewhat academic, as beech is now rarely planted pure. Early practice in this country was to plant at close spacing, and on chalk downlands (Pontey 1808, Strickland 1812) it is clear that early closure of canopy was regarded as a matter of importance. Spacings of 3 ft.×3 ft. or even closer are mentioned. Where coniferous nurses were used, and given a reasonable level of survival, canopy closure must have been extremely rapid. There are a number of considerations in deciding the most suitable

TABLE 7: SEASON OF PLANTING AND PLANTING LOSSES IN BEECH. QUEEN ELIZABETH FOREST

Losses

Date of Planting	*Expt.* 27, 1938/39	*Expt.* 37, 1939/40	*Expt.* 41, 1940/41	*Means*
Late *August*	49%	—	—	—
First half *September*	37%	71%	52%	53%
Second half *September*	12*%	51%	37%	33%
First half *October*	13*%	30%	29%	24%
Second half *October*	14*%	23%	34%	24%
November	32%	65%	—	49%
January	25%	55%	38%	39%
February	31%	69%	56%	52%
First half *March*	39%	44%	—	42%
Second half *March*	—	65%	40%	53%
First half *April*	53%	81%	33%	56%

* Significantly low values.

planting spacing. Leaving aside the considerations which are quite general to all plantations, the important factors on chalk downlands seem to be rate of closure of canopy and stem form (particularly of beech). Speedy closure of canopy is highly desirable, but it is cultivation and the spacing and proportion in mixture of the nurse species which are most likely to govern this, and not so much the spacing of the beech component. Stem form of beech in many chalk downland plantations leaves very much to be desired. No doubt in many cases poor seed origin has had something to do with it, but there is even less doubt that the silvicultural conditions are also at fault. Exposure, frost and insects may cause forking and other deformations, and slow closure of canopy prolongs the period before competition can exercise any control. The proportion of beech stems of good form we can expect on open downland is not high. Recent experiences in planting with overhead cover suggests that at least one in every five will develop a satisfactory stem, but this would probably be an over optimistic estimate on chalk downland. Some such figure as one in nine might be nearer the mark. So far as the spacing of the beech is concerned, this might be interpreted that however the mixture is arranged, there should be at least nine beech within range of any position at which a final crop tree is desired. Arrangements in mixture will be touched on in the next chapter, but even a cursory study of existing chalk downland plantations will suggest that the beech component of the crop, at least, can hardly be planted too closely.

APPLICATION OF FERTILIZERS

The few experiments which have been carried out offer little encouragement for the use of fertilizers, at least at the time of establishment. Young beech at Queen Elizabeth Forest made no appreciable response to either phosphorus (applied as bonemeal) or potash (as sulphate). Bonemeal, however, had some effect on *Thuja plicata* and *T. occidentalis* in the same forest, decreasing the death rate from 12 per cent to 7 per cent and improving growth by a small and unimportant amount. Oregon alder also showed some small responses to phosphorus (as slag and bonemeal).

From agricultural experience of chalk soils, one would certainly expect responses to potash. It may be that beech is not in a position to respond in its early years because of the physical difficulties of the site. Scots pine on the other hand has exhibited considerable responses to potash in King's Forest, where the soils are sands overlying the Chalky Boulder Till. (Benzian (1955).)

This is of interest since it is the only case of an appreciable benefit from potash applied at the time of planting in this country. It was not however a gain of practical importance, since the growth of the unmanured transplants here was perfectly adequate.

Experimental manurings on other types of grassland have often shown that whether or no there is any effect on the crop, the grass is likely to respond first and the increased growth may be harmful. This is likely to be most noticeable with nitrogeneous manures.

One might expect useful responses to both potash and nitrogen in crops where canopy has formed, but no work has been done at this stage.

Since chlorosis is a nutritional disturbance brought about by the failure of the plant to take up, or use, certain minor elements in the presence of excess free lime, the application of the elements to the soil or direct to the foliage might appear to offer some promise. Chelates, stable organic compounds of iron and other metals, have been used in horticulture against chlorosis, but this sort of thing hardly seems practicable on the forest scale. Foliar applications may however be very useful in diagnosis.

TENDING OF YOUNG PLANTATIONS

The special feature of chalk downland plantations which has a bearing on tending operations is, of course, the serious grass competition, which is almost certain to be of some significance however careful the initial cultivation. The nature of the vegetation which develops after the plantation has been formed is primarily dependent on the site, but the form of cultivation may also be of importance. For example, complete ploughing is often followed in the first place by a strong invasion of composite weeds, yarrow, sow thistle, coltsfoot, etc. These may not be as strong competitors as grass, but may be a nuisance by their mere luxuriance. (At Arundel, complete ploughing in 1955 gave rise to an almost pure stand of yarrow!). Complete cultivation by discing, rotovating etc., if only carried out as a single operation, does not give very efficient control of the original grasses and these may recolonise the site within a season. There is a tendency with any complete cultivation for coarser grasses to come in at least temporarily; for example cocksfoot may replace fescue and *Agrostis*. Partial cultivation, single furrow or double mouldboard, does not change the vegetation much, but the luxuriance of the existing grasses may be increased where soil has been thrown out, hence the furrow is often quite rapidly invaded from the edge.

Weeding operations can be prolonged and expensive whenever a plantation has had a poor start. Beating up is carried out in increasingly difficult conditions, and the survival rate of replacements is rarely as good as that of the original plantation. Weeding of grasses is necessary to prevent actual overlaying and suppression. Unless very intensively done, it probably does little to reduce root competition. It can easily be demonstrated that grasses are most efficient competitors—particularly to broad-leaved trees. Treatments giving a complete control of the vegetation, such as hoeing, have often been compared with 'normal' weeding methods. The results of an experiment of this sort commenced at Friston Forest in 1931 are summarised in the table below. The sward in this case was a rather lush grass/herb type in a valley bottom. (See Plate 4.)

No method of inter-row cultivation in young plantations is in practice at the present time, though our predecessors seem to have integrated agriculture and forestry to the extent of cropping between the rows of trees. Ride cultivation sometimes benefits edge trees to a marked degree (see Plate 4). Powered grass cutters are sometimes used. Since the benefits to be obtained from the control of grass on many planted sites are obviously quite considerable, trials of the herbicide dalapon (which is selective against grasses) have recently been started on chalk downlands and other grassy sites.

Preliminary results are promising, but 'dalapon' must be used with caution inside young plantations, since it can damage the buds and shoots of young trees if applied while their growth is active. The indications are that dalapon sprayed (avoiding the young trees as much as possible) at rates of 10 lb. commercial dalapon per acre during October or March, may bring a useful measure of sward control.

There has always been much discussion amongst foresters on the question of the best season to weed. There is sometimes little choice, but on thin chalk downland soils the growth may not be strong enough to warrant more than one cutting in the season. The weight of experience is in favour of delaying the weeding of beech until about the second half of August. This was found to be particularly important at Friston, an exposed forest with very high sunshine records. It may be assumed that the shelter of the grass is of some value in reducing the transpiration stress on the tender beech foliage and perhaps also in preventing damage from insolation. There is actually evidence from a series of trials undertaken at Friston in 1933 that it is preferable not to weed at all rather than to weed in early summer.

TABLE 8: GROWTH OF NORMALLY WEEDED AND HOED BEECH AT FRISTON FOREST

Height, inches.

Date of Measurement	*Normally Weeded*	*Hoed*
February, 1931 ..	8.9	8.8
October, 1931	11.1	13.2
October, 1932	12.4	24.9
October, 1933	16.4	43.4
November, 1937	39.1	74.2

Chapter 5

USES OF PIONEERS AND NURSES FOR BEECH, AND ALTERNATIVE CROP SPECIES

Plantation on chalk downland has usually aimed at the establishment of beech woodland. While beech is the obvious choice on broad ecological grounds, the forester is interested in other species, either as nurses or pioneers to facilitate the succession towards beech, or as associates with beech in longer term mixtures, or possibly even as final crop species on their own merits. These are not mutually exclusive categories, since plainly a tree might serve more than one purpose.

Obviously enough, if a species is required for a longer term it must be better adapted to chalk downland soils than if it is only needed for some ten to twenty years. This distinction is the clearer the shallower the soils over the chalk. Many conifers, perhaps even most, will exist for twenty years or so on chalk if there is something like a foot of rootable material available. If this is acid to a depth of even a few inches, they will thrive correspondingly longer. The list of conifers which can be relied upon to thrive to any age when the whole of the root system lies in a highly calcareous medium is certainly restricted, but because a species is known to be susceptible to chlorosis is not to say that plantations of it on such a site are doomed to a hundred per cent failure. The onset of chlorosis frequently occurs in the thicket stage of plantations, and it is a common phenomenon that individuals which escape it (often these are to be found in the margins of plantations) may remain vigorous and healthy for many years afterwards.

It is rather difficult to be clear which of the principal restrictions on a chalk soil is most important to a particular species, and there is certainly a great deal which we do not know about the relationship between physical and the nutritional restrictions. It is clear that shallow chalk soils, particularly those on southern and western aspects, are extremely limited in their moisture supplying powers, and this alone will be a great restriction to the choice of species. Hence lowish moisture requirements would seem to be an important characteristic of a chalk tree. But obviously a tree which can root vigorously into the shattered chalk and satisfy its nutritional needs in such an environment is better able to draw on what moisture there is than a tree which is likely to be constitutionally upset in a cal-
down-wash soils full of finely divided chalk. These
careous root-run. Under the more extreme conditions it may not be difficult to appreciate what is happening. For instance, some of the best examples of early chlorosis have occurred with Scots pine on
soils are often deep and easily rootable and it seems clear that under these conditions the chemical greatly outweighs the physical. It is however not usually so simple. A typical downland soil is a rendzina or rendziniform soil providing twelve inches or so of free rooting conditions, and grading through weathered chalk rubble to the more or less fissured chalk itself. Here the performance of the tree will turn very much on its power of rooting such a soil deeply and vigorously, but this may not be very closely related to the susceptibility of the species to lime-induced chlorosis. Scots pine seems to have an efficient searching root system, capable of rooting all available fissures, but is highly prone to chlorosis. *Thuja plicata* on the other hand, which seems to be much less prone to this trouble, has a less penetrative root system on chalk, and might be expected to experience correspondingly greater physical restriction; resulting later in impaired vigour and perhaps instability. Drawings of excavated root systems of Scots pine and *Thuja plicata* growing on rendzina soils at Queen Elizabeth Forest are shown in Figs. 4 and 5.

Calcareous soils do not limit the choice of broadleaved species to the same extent, but the physical restrictions of downland soils will limit all but a few species to unprofitable rates of growth. A further important consideration in the choice of species is pioneering ability. This is not closely related to the ultimate suitability of the species to the site, since the tree may merely be required to grow on it for a relatively short period. Pioneer or nurse species are, as the terms imply, used in two broad ways to assist in the establishment of beech. Firstly, a crop may be established with the intention of succeeding it with beech—usually by underplanting—when the

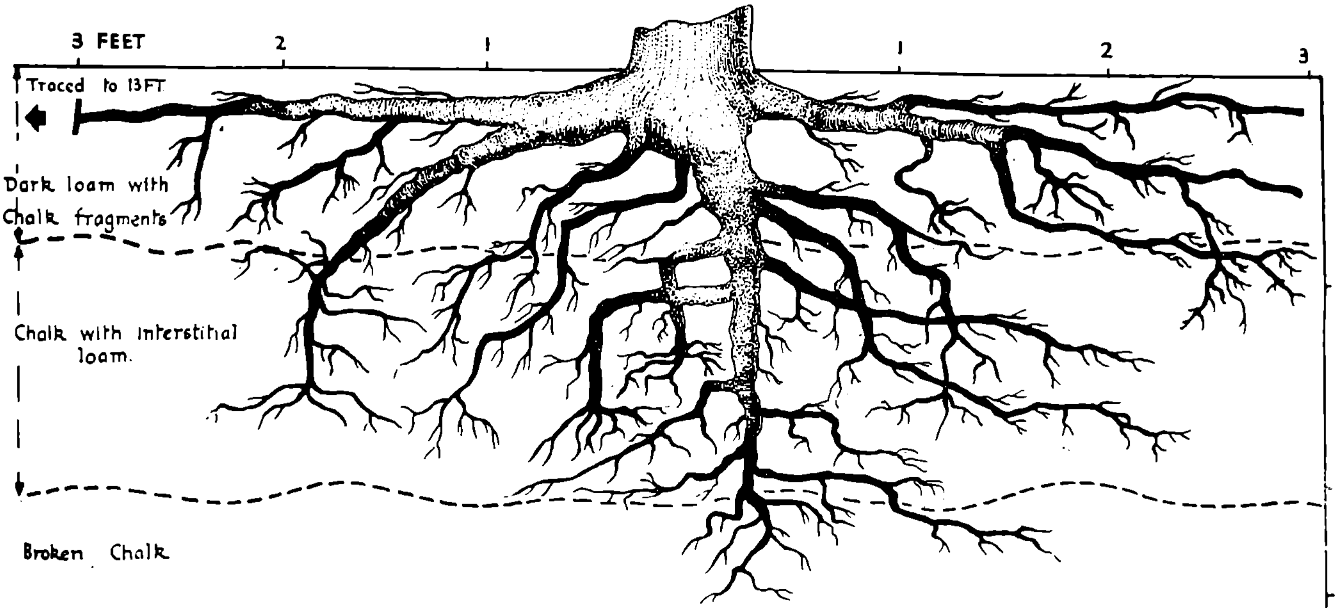

Fig. 4. Scots pine—typical root systems on rendzina. Queen Elizabeth Forest.

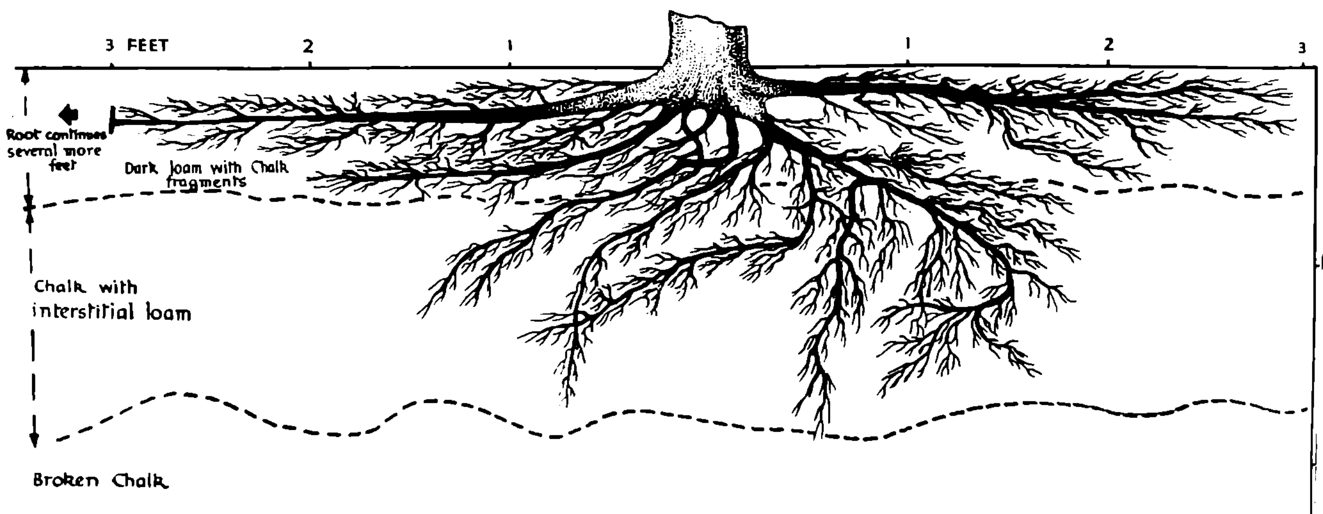

Fig. 5. Western red cedar, *Thuja plicata*, typical root system on a rendzina soil. Queen Elizabeth Forest.

conditions have become more suitable, the sward competition removed and the microclimate improved Secondly, the subsidiary species may be planted contemporaneously in mixture with the beech—as a nurse—with the object of hastening the development of the woodland condition. The latter method is the more commonly practiced. The pioneer or nurse species must, to be of any value, be markedly less susceptible than beech to the ill effects of sward-competition (which is almost certain to ensue before the closure of canopy, no matter how careful the preliminary cultivation), and it should also be spring-frost hardy.

It should also have that somewhat elusive quality of 'plantability', it should not be a species subject to heavy losses on planting when conditions are difficult. In practice, ease of establishment and the desire for early returns has narrowed the field to conifers, and for these essentially dry sites the pines have been the obvious candidates. In the establishment of beech woodland on chalk, one of the most important questions has always been what subsidiary species to plant in order to get a useful return whilst facilitating the establishment of the beech. There is certainly no general answer, since the most efficient pioneers are not the trees which are likely to survive the longest on chalk, and a few of the trees which do seem least prone to chlorosis are rather difficult to establish on open downland. Our experience of conifers other than those which have qualifications as pioneers is distinctly limited.

The Forestry Commission's own experimental work at Queen Elizabeth and Friston Forests has included the trial of a considerable number of species; some fifty-two have been planted at these sites between 1927 and 1960. A number of these were established specifically to serve as pioneers for the later introduction of beech, others were planted for more general study. It is general experience that the choice of species on difficult sites becomes wider, once cover has been obtained, hence efforts have been made to esablish a number of trees which would certainly not be of use in planting on bare downland.

There are also many records of experiences with various species on chalk from other places, including a fair amount of arboricultural evidence. No attempt will be made here to make a comprehensive review of the behaviour of tree species on chalk, but the performance of those which have been most planted will be discussed later in the chapter, and some notes will be given on others which show some promise. Mention will also be made of species against which there is some definite evidence. It will however be convenient first to say something about the use of pioneer and nurse crops for the establishment of beech.

EXPERIMENTS IN THE USE OF PIONEER AND NURSE SPECIES

Experimental work at both Friston and Queen Elizabeth Forests on this general topic has been concerned mainly with pioneer crops as distinct from nursing mixtures. This is unfortunate, since though there is much observational evidence for the efficiency of nursing mixtures on chalk downlands, we are short of direct experimental results, particularly for those species which have proved themselves most valuable in large scale practice.

The experiments at Friston include one enquiry into nursing mixtures, Expt. 3 established in 1927. This compares pure plots of beech, ash and sycamore with plots of these species in mixture with birch, Grey alder, European and Japanese larch respectively. Each of these nurses appears in separate plots as a 25 per cent and as a 50 per cent component of the crop. The experiment is established in two sections on different sites, the first being ploughed (but low and frosty) ground, the second, unploughed rough grassland.

The history of the experiment is rather depressing, since nurse crops experienced almost as much difficulty with exposure, frost, drought and sward competition as the main crop species. After twenty years little general nursing effect was perceptible. On old rabbit warrens in the upper series, better development took place (a common and instructive phenomenon, see Plates 9, 10 and 12), and here the superiority of the higher proportion of nurses (50 per cent) was plain enough. By 1941 it was obvious that none of the nurse species provided a reliable solution to the problem, and the unploughed section of the experiment was planted up with Corsican pine. As canopy has developed, hopelessly checked and languishing beech, ash and sycamore have responded and are growing up with the pine.

Although the experiment as a whole cannot be considered a success, it has provided some interesting (if belated) examples of nursing effects. These are most striking in the lower, ploughed section. Ash and sycamore are still not in canopy after thirty years without nurses, or where the nurse crop has proved quite unsuitable. Quite good growth however is to be seen in some of the mixtures with alder, and where Grey alder has spread by root suckering into pure crops of ash, there has been a marked response by the latter species.

There are several other examples of successful nurse effects from Grey alder at Friston, mainly with beech. On the more difficult soil conditions however there have been widespread failures. The larches in this experiment proved of little value. One plot of birch (on an old warren) grew well, and beech in mixture with it developed very satisfactorily. (See Plate 11). Generally however birch was not a success. It was most unfortunate that no pine was included in this experiment at the outset.

Pioneer Crops

Three experiments dealing with various pioneer crops for the later introduction of beech were established at Queen Elizabeth Forest during the years 1930/32. One of these, Experiment No. 7, 1932, is sited on a typical chalk soil on War Down, the older two on Holt Down have deeper soils derived from some residual material. Species used as pioneers in these three experiments were:—

- Scots pine*
- Austrian pine*, (*P. nigra* var. *austriaca*)
- Two other regional forms of *Pinus nigra* (var. *cebennensis* from Spain and var. *caramanica* from Turkey)
- European larch*
- *Cupressus macrocarpa*
- *Sorbus intermedia*
- Birch
- Three alders (*Alnus glutinosa*, *rubra* and *incana**)

*The species asterisked are common to all three experiments.

The general form of the experiments provides a comparison of:

(*a*) Beech planted pure at the time of the establishment of the pioneer species with

(*b*) Beech introduced at various times and in various patterns into the several pioneer crops.

Comparisons of beech planted on open grassland with beech planted under pioneer crops *in the same season* are not included. This is a disadvantage, but since the behaviour of beech introduced into pioneer crops is consistently very different from that planted pure on open downland, one may safely ignore the seasonal effect.

The pure beech plots in these Queen Elizabeth Forest experiments have grown fairly well after a very slow start, attaining heights of about twenty feet in twenty years. They were, however, only fully exposed in their early years, and have become increasingly sheltered by neighbouring plots of faster species) the 'pioneers', for later introductions of beech).

Of the various species (listed above) tried as pioneers at Queen Elizabeth Forest in the three main experiments, several showed themselves to be of little value for the purpose. *Cupressus macrocarpa* is too uncertain in establishment, birch is not easy to establish either, and is slow in suppressing the ground vegetation, and *Sorbus intermedia*, though appearing perfectly at home on the chalk, is also too slow in suppressing the sward. As pioneers, Scots and Austrian pines proved the most effective species. The alders and European larch were only successful on the deeper soils (*Alnus cordata*, which will be mentioned later, was not concerned in these experiments).

Introduction of Beech to Pioneer Crops

As the pioneer crops developed a suitable degree of canopy, beech was introduced in irregular groups. Use was made of existing gaps, and further openings were made by cutting out nurse trees to provide space for at least 2,000 beech per acre, with no group more than fifteen feet from the next. The beech plants were set at the close spacing of 2–3 feet within each group (see Plate 13). In the case of some of the alder plots in Experiment 1 the beech were introduced as early as three years after the nurse species, because on the deeper soils the alder got away very quickly, but most of the introductions were made from nine to twelve years after the initial planting. In the European larch and alder on the thin soil in Experiment 7, the beech were not put in for thirteen years; and quite recently (1952), beech have been introduced into 22-year-old plots of Scots and Austrian pine (averaging 28 feet in heigh) by removing every other three rows of pines and introducing three rows of beech into the felled strips (Experiment 2, 1931).

These experiments by no means represent a comprehensive investigation into the subject. The age of the pioneer crop has been but little studied, for instance. But a number of general conclusions can be drawn:

(i) **Planting Losses** have usually been very much lower where beech has been introduced to pioneer stands than when planted in the open. Direct experimental evidence is lacking, but the results at Queen Elizabeth Forest are confirmed by much general experience in the use of cover elsewhere. It seems clear that, not only are initial losses far less, but the tendency for plants to die out gradually for many years after planting is greatly reduced also.

(ii) **Growth Rates.** Early growth of beech has been much faster when introduced into a suitable nurse crop than when planted in the open. This is illustrated in Fig. 6. The long period of slow height growth during which the beech is gradually getting the better of the sward is not represented where the beech has been introduced to crops which have already closed canopy.

(iii) **Stem Form.** Judged on the prevalence of unforked stems, stem form of beech introduced under cover is superior to that of beech planted in the open. Plate 22 shows beech in Experiment 7 at Queen Elizabeth Forest which have been planted in a group in a Scots pine crop established ten years earlier, and may be contrasted with Plate 23 which is fairly typical of pure beech at the same forest. The closer spacing of the beech in the pine crop may well have

Plate 17. Western red cedar, *Thuja plicata*, aged 16 years, at Friston Forest, 1954.

Plate 18. Monterey pine, *Pinus radiata*, aged 27 years. at Friston Forest, 1954, shortly before the onset of dieback.

Plate 19. Italian alder, *Alnus cordata*, aged 16 years, at Queen Elizabeth Forest, 1951.

Plate 20. Small-leaved lime, *Tilia cordata,* aged 16 years, at Queen Elizabeth Forest, 1951.

Plate 21. Beech, aged 11 years, showing beneficial edge effect from ride cultivation. Crawley Down, Hursley Forest, Hampshire, 1939.

Plate 22. Good form of beech, aged 18 years, raised in Scots pine matrix, Queen Elizabeth Forest, 1960.

Plate 23. Poor form of beech, aged 28 years, raised in pure plots, Queen Elizabeth Forest, 1960.

Plate 24. Fifty-year-old Norway spruce on thin chalk soils, Queen Elizabeth Forest. Mean top height, 56 feet; mean girth of dominant trees, 32 inches.

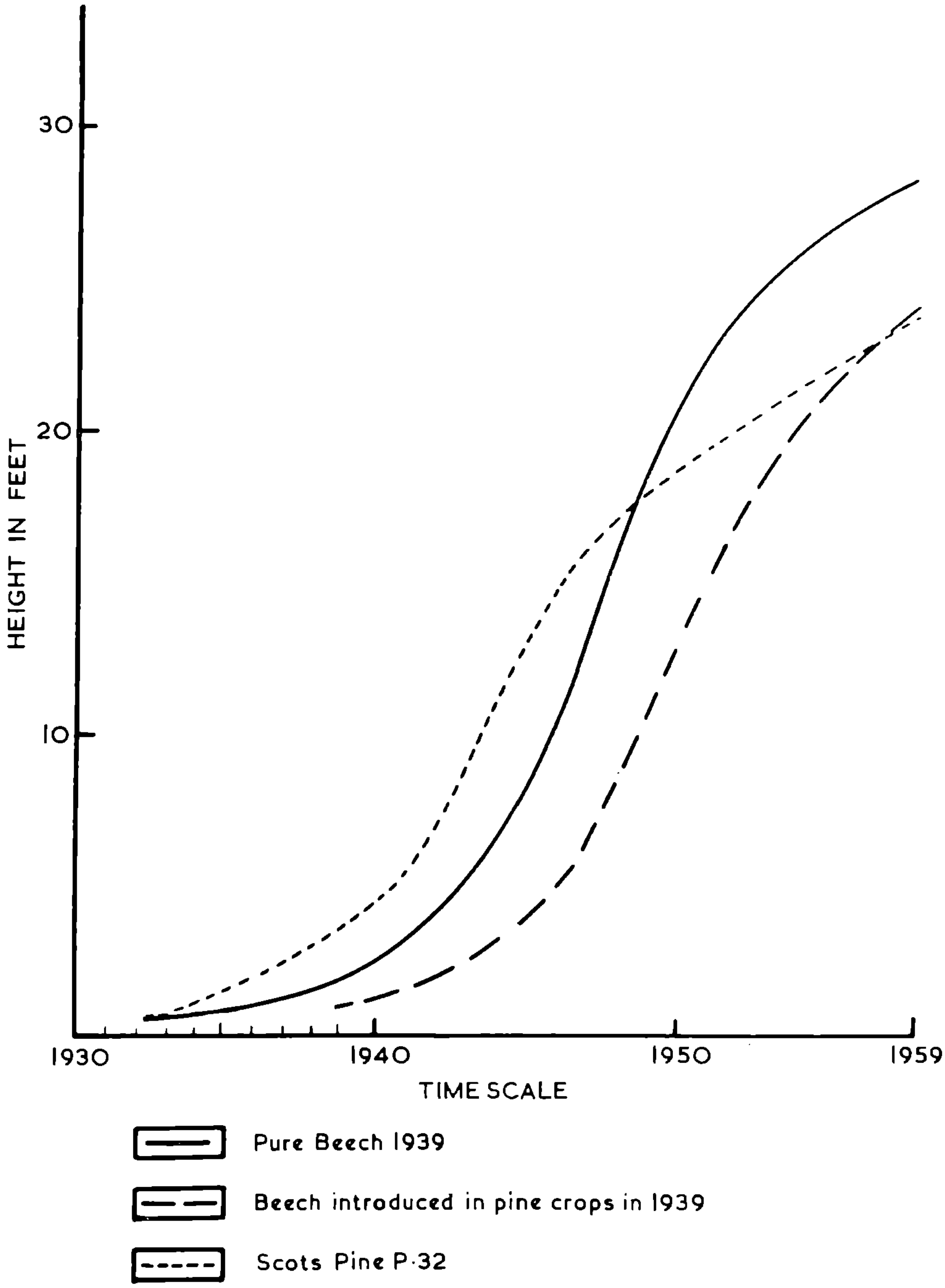

Fig. 6. Height growth of beech, pure and in pioneer pine crops. Queen Elizabeth Forest.

something to do with the superior stem form, but improvement of stem form in beech due to the presence of cover seems to be of general application. There appear to be two main factors, the first is the reduced incidence of frost injury to leading buds, and the second is the flatter branch arrangement, which in itself discourages the development of equal forks. This is mainly due to reduced light intensity.

(iv) The introduction of beech to vigorous young pioneer crops which are just entering the thicket stage makes for considerable tending difficulties, producing as it does extremely intimate contact between the beech and the nurse trees. All the successful pioneers have required firstly much branch pruning and subsequent early and heavy thinnings to maintain the beech in full vigour. There are no experimental comparisons with contemporaneous mixtures, but there can be little doubt that these would be much easier to manage.

(v) In general, the advantages of nurse crops for beech, and other exacting species, have been more marked at Friston than at Queen Elizabeth Forest. It seems likely that this is because Friston is firstly a drier environment and secondly much more affected by salt winds. There have been frequent reports over the years of many species being severely damaged by gales blowing in from the sea. The benefit of shelter at Friston is well illustrated in Plates 6 and 7.

As already stated, the stage at which introductions of beech should be made into pioneer crops has not been fully studied experimentally, but having due regard to both economic and silvicultural considerations, it would seem that the best time to bring in beech is in the early pole stage when all ground vegetation has been suppressed and when the pioneer crop is of saleable size.

An interesting example of a possible method not included in any of the experiments has been provided by a war-time occurrence at Friston. During the early days of the war an incendiary bomb fell in the 1927 Corsican pine in Compartment 5 and caused a gap about 45 ft. × 20 ft. In 1941 this gap was planted up with beech at 3 ft. × 4 ft. spacing, the Corsican pine being approximately 11 to 14 ft. high at the time. The beech grew well from the start and by 1952 (i.e. in twelve years) had reached a height of 17 ft. Its form is unusually good with very few bends or forks. The soil is not particularly deep (approx. 12 in.), and this general behaviour is quite unusually good for this difficult site. Plate 12 illustrates the crop, and in Fig. 7 its height age curve is compared with those for several other methods of establishment, represented in experiments. While it would be incautious to recommend a technique on the strength of one bomb-hole, one feels that the cutting of largish groups in a pure conifer crop might well be given further attention. Of the favourable factors in this accident, the most important seems to have been that the Corsican pine crop had reached a suitable height to suppress the sward very thoroughly and to provide much side shelter, whilst still being wind-stable and capable of further height growth.

Pioneer Crops Versus Mixtures

It is not possible to say whether it is better to use a pioneer crop than to plant a nurse in mixture with the beech. The objects of management may frequently require the establishment of broadleaved woodland as quickly as possible, and the latter will be the only course open. But if amenity considerations do not preclude it, there seems no reason why a pine crop should not be grown to the pole stage before introducing beech in some convenient pattern of strips or groups.

It is however notable that many of the more recent mixtures of Corsican pine and beech appear likely to be very successful. The 3-row/3 row mixtures of Corsican pine and beech at Brighstone (Isle of Wight) and Blandford, Dorset are good examples. Here successful methods of ground preparation have given both species a good start. It is sometimes argued that mixtures of this pattern are not sufficiently intimate to benefit the nursed species in the early stages. There is some truth in this. Certainly were initial costs not an important consideration, there is no doubt that very intimate mixtures at close spacing would be a good way to establish beech plantations on chalk downland. It is, of course, not only a matter of the costs of plants and planting, but of subsequent tending. A pattern of three rows of the nurse is always useful in that two whole rows in contact with the nursed species can be removed whilst still leaving the central row, or some trees in it. If a higher proportion of the nursery conifer is desired, pines can always be introduced in the beech rows.

Shrubs as Nurses

Shrubs have occasionally been tried as nurses for beech. Broom (*Sarothamnus scoparius*) was sown on some scale at Friston in the early years, but was not persevered with, following heavy failures. These were, at least in part, attributable to the depredations of slugs amongst young seedlings. But where broom succeeded locally, there was little doubt about its beneficial effects on beech within its shelter. Experimental broom sowings were carried out at Queen Elizabeth Forest (War Down) in 1939 and 1940. Sowings were in continuous bands 9 ft. apart, and beech and *Thuja plicata* were planted between the hedges in 1945. Both species developed excellently, beech attaining 15½ ft. and *Thuja* 16 ft. in fourteen

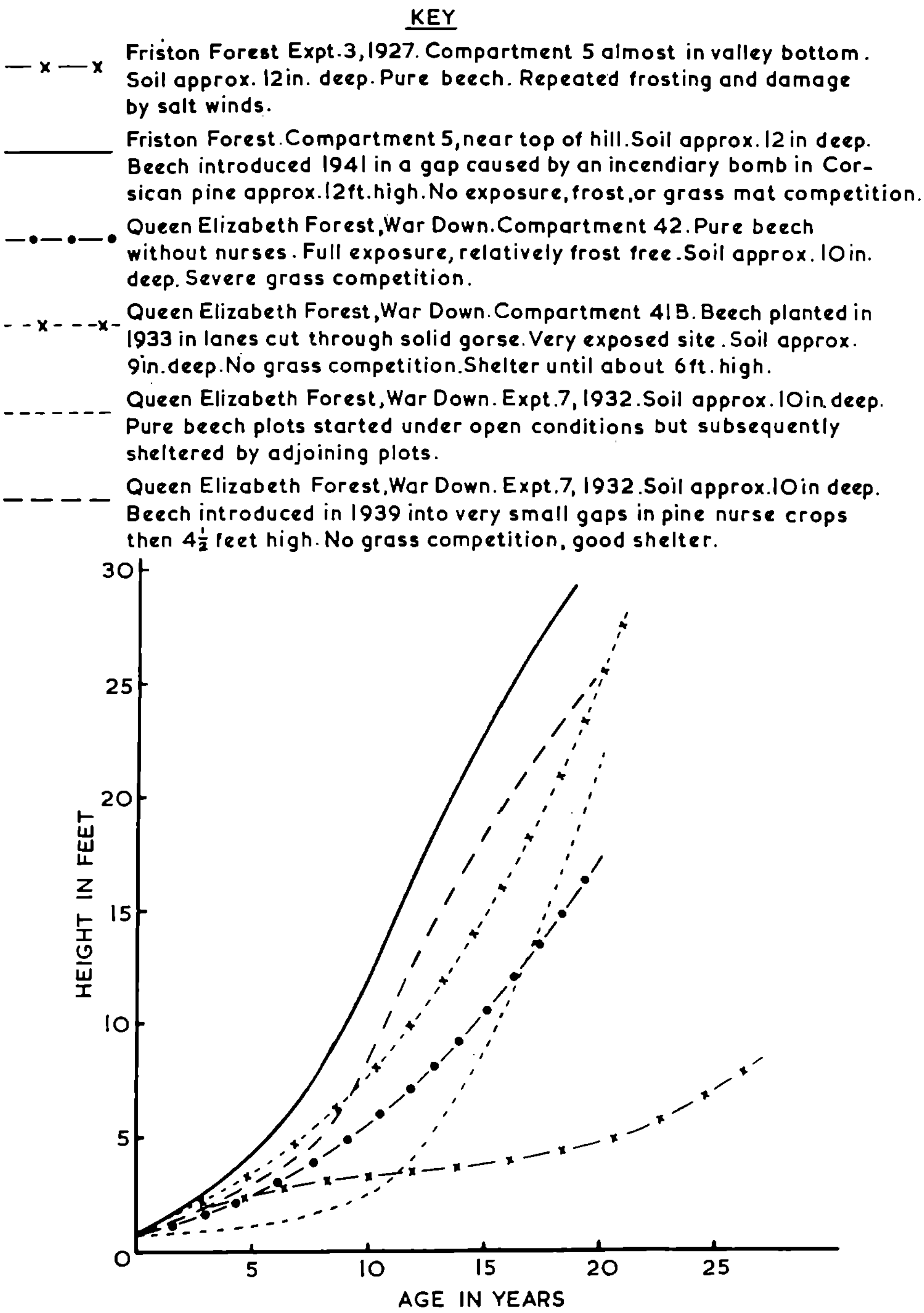

Fig. 7. Beech. Height age curves for various sites and methods of establishment.

seasons. Broom is not at its best on highly calcareous sites, and is apt to be short-lived. Spanish broom (*Spartium junceum*) is apparently much longer lived. A shelter belt at Friston, sown alongside the main Eastbourne Road, retained its vigour for twenty-five years. It is not nearly so dense a shrub as common broom, and probably of limited value as shelter.

Gorse (*Ulex europaeus*) is not likely to attract the forester, since it is expensive to keep in control and provides a serious fire hazard into the bargain. It has occasionally been sown for game cover, and two such patches at Queen Elizabeth Forest, established in the mid-1920's, were planted with beech in 1933 by cutting racks through the dense thicket of gorse at about 4½ ft. intervals. The development of the beech in the gorse was far superior to that planted on adjacent open ground. Comparative figures are given in Table 9 below.

It is difficult to say what part of this apparently very large nursing effect may be ascribed to nitrogen supply. The well-known nursing effect of broom on *Calluna* heaths is certainly due in great part to nitrogen. It is curious that a dense thicket of gorse should not, apparently, compete with the beech for moisture to any serious extent, but possibly it intercepts less rainfall than a downland sward.

Generally speaking, there is little attraction in establishing nurse crops at considerable expense from which there is no chance at all of obtaining any return, and the use of shrubby species has had little attention.

SUBSIDIARY SPECIES

Several of the species commonly used as nurses or pioneers have been mentioned above. The choice is distinctly limited, but variation in soils does allow a certain amount of flexibility. It also seems possible that species which have little pioneering ability might be brought in later as associates for beech, perhaps underplanted in mixture with it below pioneer crops.

Pines: General

The pines, and especially Scots pine, have always been the most important chalk pioneers. Austrian pine (*Pinus nigra* var. *austriaca*) appears to be the most lime-tolerant. Owing to its rough branch habit, it is not usually considered worth planting in its own right, but it is an extremely valuable tree for shelter belts and cannot be equalled as a nurse or pioneer for beech on the thin rendzina soils. Its near relative, Corsican pine (*P. nigra* var. *calabrica*), is distinctly less tolerant of lime, but has usually compared favourably with Scots pine on sites where the latter has shown symptoms of chlorosis at an early stage.

Scots Pine

Scots pine seems to have been curiously neglected in the Forestry Commission's early chalk plantations; it appeared on the scene at Friston in 1931 as a 'beat-up' in Corsican pine/beech plantations, and it was not regularly planted in mixture with beech till 1938. But shortly after this it became the favoured nursing species at both Friston and Queen Elizabeth Forests. It has very considerable advantages. It is easy to establish, and very resistant to drought and spring frost. Its early growth is usually faster than that of Corsican pine and its powers of vegetation suppression are better.

It has more records of lime-induced chlorosis than any other conifer, though this partly reflects the extent of plantation. There is no doubt, however, that it is very liable to chlorosis and early death on shallow calcareous soils, especially those with no acid surface material at all.

The really important question is not whether Scots pine will eventually fail, but whether it can be relied on to do its job before it does. Generally speaking, the answer seems to be 'Yes'. A recent survey of certain Forestry Commission chalk plantations, in which Scots pine has been dying sporadically for some years, indicates that failure rarely takes place before the tree has reached a height of about fifteen to eighteen feet. Nor fortunately does the whole of a nurse crop become affected at one time. By this time beech should be well established and the succession far advanced. It is, however, of prime importance that the plantation should be well stocked, as the failure of the nurse crop in gappy, open plantations can be most serious, and may lead to a set-back in the establishment of woodland conditions.

Although Scots pine has been successfully used as a pioneer for beech in the experimental plantations at Queen Elizabeth Forest, there is obviously some

TABLE 9: BEECH PLANTED IN GORSE AT QUEEN ELIZABETH FOREST

Mean Height.

	1937	1953
Beech planted 1933, in gorse	46.5 inches	28.1 feet
„ „ „ , open down	17.3 „	17.4 „

risk attached to this use of the tree. It happened that with the rather early introductions of beech, the pine crop had some years of life before chlorosis set in. In fact pines began to die very conveniently at this stage when the beech was beginning to require release (see Plate 10). Had the pines been left for underplanting in the pole stage, it is possible that much of the crop might have died before the beech could be established. Scots pine is best considered as a nurse for contemporaneous mixture with beech. It should certainly not be relied on as a long-term component of the crop. However, it is a mistake to assume, as is often done, that deaths in a Scots pine crop mean that all the pines are going to die in a few years, or that chlorosis will be the early fate of all Scots pine crops on chalk soils.

Corsican Pine

Corsican pine finds its optimal climatic conditions in the south of England, and appreciates rapidly draining soils. Hence it is well placed to exploit any suitable downland sites. There is growing evidence, however, that it should not be planted too far north (particularly in exposed or elevated conditions where it may suffer from the condition known as dieback, which appears to be climatic in origin (Brown 1959)). Some of the more elevated and exposed chalk sites in the north may be beyond its safe limits.

One of the first projects at Friston was the establishment of a belt of Corsican pine along the seaward exposure of the forest. The part of this belt planted in 1927 was of the true Corsican origin of *Pinus nigra* var. *calabrica*, the later part planted in 1931 consisted of the so-called 'Ursuline' type; (a form of *P. nigra* imported about that period of which the precise origin is still uncertain, though it appears to have been collected at high elevations in Corsica). Corsican pine was, somewhat later, used as a nurse to beech at Friston, though heavy planting losses and slow early growth proved serious disadvantages. It has, however, continued to be regarded as the most useful coniferous associate for beech on the southern Chalk.

Corsican pine has been planted in mixture with beech at Blandford Forest (Dorset) and Brighstone (Isle of Wight) and many of these plantations appear very successful. It is not an easy tree to establish, and on chalk much depends on obtaining a good take and fast early growth. Adequate cultivation has undoubtedly been an important factor in the later plantations of Corsican pine. Many foresters regard it as the most suitable nurse for beech, placing much weight on its tolerance of lime. This in fact is an advantage in long-term mixtures, but it is doubtful whether it is significant where the tree is regarded solely as a nurse.

In the south, one can usually rely on Corsican pine to produce at least a pole crop, and except on thin soils on southern aspects, or where there is extreme exposure to sea winds, one would normally expect it to reach small sawlog dimensions at least. If a coniferous rotation is allowable, Corsican pine might be planted pure on many chalk sites. Suitable opportunities for bringing in beech occur in the early pole stage, when it will be necessary to cut out strips or groups, or somewhat later for uniform underplanting following a heavy thinning.

Other Pines

There has been relatively little experience of other pines on chalk downland. Monterey pine, *Pinus radiata*, grew vigorously at Friston for some twenty years before chlorotic symptoms showed themselves and most of the trees succumbed. The plot however averaged twenty-six feet in height, with breast-height quarter girth five inches, before trouble set in; some surviving trees seem likely to reach very considerable dimensions. The extreme vigour of *Pinus radiata* in south coastal climates gives it a fair chance of reaching merchantable dimensions, but it is plainly susceptible to chlorosis (see Plate 18).

Lodgepole pine, *Pinus contorta*, has been little planted on the chalk and there is no evidence as to its susceptibility to chlorosis on chalk soils, since what plantations there are have hardly had time to develop symptoms.

Spruces

The spruces would not be expected to play any great part on rapidly draining soils in districts of somewhat low rainfall. Sitka spruce may certainly be dismissed on these grounds, but Norway spruce has developed surprisingly well on a number of chalk sites. It does not appear particularly susceptible to chlorosis, and it is plainly very much less so than Scots pine, since it has continued to flourish in mixture with the pine on thin chalk soils where the latter is succumbing to chlorosis. It has been seen in health at sixty or seventy years with breast-height quarter girths of fifteen inches, on soils reacting vigorously with acid right up to the litter. What older crops of spruce have been seen on thin soils have been partially stocked, often with broadleaved trees in mixture, and providing little evidence on yield of regular plantations. There is however more than a suggestion that Norway spruce can be a productive species on chalk soils. It is extremely probable that its establishment on open downland would be slow and difficult, and southern aspects are likely to be altogether too dry for it. But where conifers are required for other than a short nursing period, Norway spruce might well be tried in mixture, using the best general cultural methods for its establishment. (See Plate 24.)

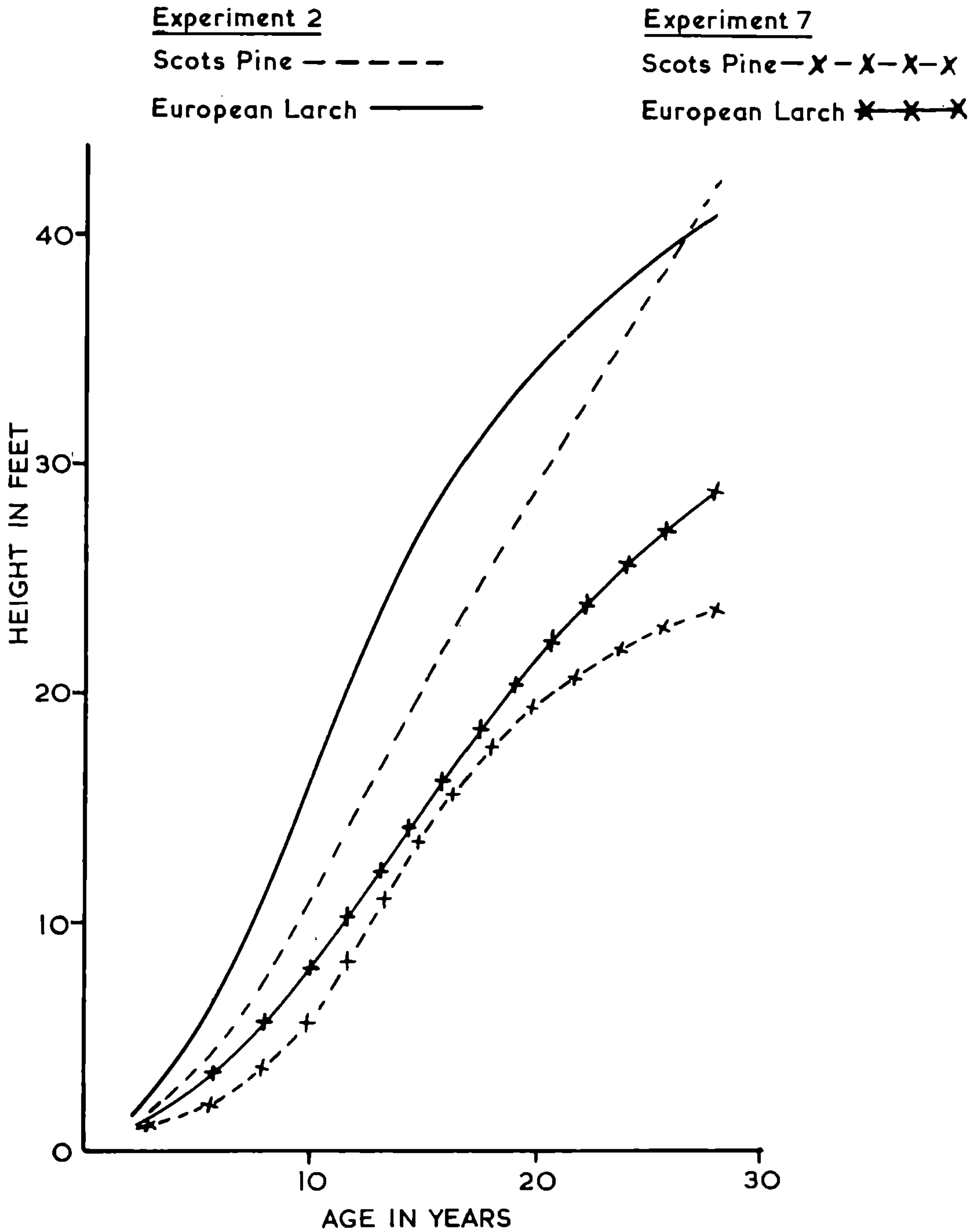

Fig. 8. Growth of Scots pine and European larch on two different soil types.
Queen Elizabeth Forest.

The Serbian spruce, *Picea omorika*, appears to be a plausible suggestion, since it inhabits limestone country in Jugoslavia. It has shown some promise on limestone soils, and also on sands over the Chalky Boulder Till in East Anglia. As it tolerates fairly dry conditions for a spruce, it seems likely to grow at least as well as Norway spruce on chalk downlands.

Larches

European larch has been planted on the chalk over a very long period, usually in mixture with beech. Scots pine has often accompanied it in such mixtures. In the Forestry Commission's earliest chalk downland plantations the first nurse used was European larch, which was planted in mixture with beech from 1927–1931 at Friston and from 1928–1930 at Queen Elizabeth Forest. The results at Friston were extremely unsatisfactory on the shallower soils and particularly in the more frosty localities, and the use of larch on a large scale was accordingly abandoned. Exposure to salt winds at Friston was undoubtedly an additional adverse factor. At Queen Elizabeth Forest, larch did not prove a universal failure, and on soils of a reasonable depth (eighteen inches or more over the solid chalk) quite good results have been obtained, and intermediate yields from the larch have proved of some value. A serious disadvantage of European larch is that it does not suppress grass sward quickly.

European larch has fallen into disfavour, but to some extent this has been due to the planting of unsuitable provenances. Much larch of high Alpine origin has been planted on the southern chalk, and there is no doubt that where frost and exposure are important factors, Alpine larch will compare very unfavourably with larch of Scottish, Sudeten, or Polish origin. Larch has, however, grown poorly on the shallower rendzinas, and there is a big difference between its behaviour on the Clay-with-flints cap on Holt Down and the rendzina on War Down, Queen Elizabeth Forest (see Fig. 8). European larch does not seem to be very prone to chlorosis, and certainly on War Down it has survived very much better than Scots pine. The appearance of the larch in the experimental plots at Queen Elizabeth Forest is perhaps better than it was ten years ago.

Larch is a traditional choice of species in the Yorkshire Wolds, and it may be that the lower evaporation rates of the north suit it. Young plantations of the 1940's in Scardale Wolds Forest, where larch has been planted in mixture with beech, appear most promising. Some of these recently observed have been of good seed origins, Scottish, Sudeten, and middle elevation Austrian, all sources which have shown up well in provenance experiments.

Japanese larch has occasionally been used as a nurse for beech. The south-eastern chalk climate is undoubtedly too dry for it, and though the experience of it is limited, there have been instances of particularly early deaths from lime-induced chlorosis.

Douglas Fir

Douglas fir, like Corsican pine, is a species responsive to warmth and free draining soils, though its moisture requirements may be somewhat greater than those of the pine. It is not climatically illsuited to any of the southern chalk except by its sensitivity to wind, which will be against it on the most exposed downs. It has no claims as a pioneer of open downlands since it is difficult to establish on exposed and dry grassy sites, and it is also frost susceptible. There are a number of instances of good performances of Douglas fir on chalk, but in most cases which have been studied there has been some acid material over the calcareous subsoil, and it is noticeable that most of the successful examples of Douglas fir plantations are on old woodland sites. There are few records of chlorosis, but at Hursley Forest, Hants., Douglas fir suffered severely on a down-wash soil containing much free lime. Nearby on a 'shallower' but lime-free soil (Clay-with-flints) the tree remained healthy.

Thuja plicata

This species has recently attracted favourable attention. At Queen Elizabeth Forest it has reached 16 ft. in height in fourteen years, on a rendzina soil with chalk at nine inches, whilst at Friston it is still very healthy after twenty-one years on an even shallower soil (see Plate 17). A case has been reported where *Thuja*, in mixture with Scots pine, showed no adverse symptoms, whilst the pine crop was succumbing to lime-induced chlorosis. It is of some interest in this context that *Thuja plicata* shows its optimal growth as a seedling at a soil reaction distinctly less acid than that favoured by its north-west American associates, Sitka spruce, Lodgepole pine and Western hemlock (Benzian, unpublished).

Thuja is difficult to establish in open downland conditions. A possible role for *Thuja* might be as an associate for beech planted under cover of pioneer crops of pines.

Lawson Cypress

Lawson cypress has also established some claim as a chalk tree, and it is one of the few conifers one sees doing reasonably well in gardens on chalk. Its early behaviour in trial plots at Queen Elizabeth and Friston forests is quite promising, and at the latter site, excavations have revealed that it roots vigorously into the chalk rubble. In fact its root system here appeared to be less restricted than that of any conifer in the trial plantations, including Scots and Corsican pines, *Pinus radiata*, *Thuja plicata* and *Cupressus macrocarpa*. It has already been observed that Lawson cypress is able to root into other very compact subsoils and its behaviour at Friston may reflect this useful characteristic, as well as some degree of tolerance of calcareous conditions. Lawson cypress is not a high-yielding species under any conditions, and there would be little temptation to plant it pure. It is unlikely to be a useful pioneer and under exposed conditions its form is usually very bad. But with its extreme shade tolerance, it might have some success as an associate for beech and could perhaps be used for late beating-up in unsatisfactory plantations.

Cupressus macrocarpa

Monterey cypress has some reputation as a chalk tree, based largely on horticultural experience, but also on the performance of Somerville's pioneer plantation at Poverty Bottom (see Chapter 3). It has done quite well on a shallower soil than Poverty Bottom in Friston Forest, but though appearing healthy and vigorous, it is poorly rooted and subject to wind-throw. Its hybrid offspring, X *Cupressocyparis leylandii*, has quite recently been tried on the chalk. The most that can be said at present is that it has proved easy to establish (as indeed it has on a variety of sites) and its early growth is good. Its extreme resistance to exposure will certainly be in its favour.

Other Conifers

A number of other conifers are recorded as having succeeded on chalk. Some are native to limestone formations, and might be expected to be adapted to calcareous soils. This by itself will not be a sufficient recommendation where a tree is difficult to raise or establish, and most other conifers than those mentioned seem to be of arboricultural interest only.

Quite good specimens of cedar of Lebanon and Atlas cedar are to be found on the Chalk, but plantations of either on any site are rare. Atlas cedar (*Cedrus atlantica*) is showing some promise in a trial plantation at Queen Elizabeth Forest, but has proved slow and difficult to establish.

The Spanish fir, *Abies pinsapo*, is often recommended for chalk or limestone but seems hardly worth growing. The Greek fir, *Abies cephalonica*, is a tree of better stature, but is extremely frost susceptible in youth. The Algerian fir, *A. numidica*, and the Cicilian fir, *A. cilicica*, have also been recorded as successes on chalk. The European silver fir (*A. alba*) has been little planted on chalk and certainly would have no place in the afforestation of chalk downs, but *A. nordmanniana*, the Nordmann fir from the Caucasus, which is more frost hardy and less susceptible to attack by the adelgid *Dreyfusia nüsslinii* (syn. *Adelges nüsslinii*) might warrant trial as a successor species. It has grown tolerably well on thin brashy soil over the Oolite at Cirencester (James 1951).

On present evidence it seems that Corsican pine, Norway spruce, and perhaps *Thuja plicata* and Lawson cypress are the coniferous species most likely to form a productive component of a long-term mixture with beech on chalk soils. At the risk of tiresome reiteration, however, one must repeat that all downland sites are not occupied by chalk soils, and where Clay-with-flints or other acid material is present in some depth, other conifers suited to the general climate will grow very well.

Broadleaved Species

The question of possible broadleaved alternatives to, or associates for, beech, raises a rather different set of considerations. The economic advantages of obtaining some yield of softwood from any site, whether or no the final composition is to be purely broadleaved, are clear enough. But it is not at all obvious that there is much to be gained by replacing beech on any scale by other hardwoods. As mentioned previously, few broadleaved tree species have proved of much value in speeding up the process of establishment in the afforestation of bare downland.

In the early 1930's, considerable attention was paid at Friston and Queen Elizabeth forests to the Grey alder (*Alnus incana*) as a nurse for beech, encouraged by the successful experimental plantations of this tree on Holt Down, Queen Elizabeth Forest in 1930. But the thin Clay-with-flints cap on Holt Down proved to be the secret of its success there, and its extension to shallower soils gave disappointing results. These seem on the whole to have been due to insufficiency of moisture, rather than to any special antipathy to the chalk. Surviving specimens on shallow soils, though of no great size or vigour, appear to be rooting quite freely in fissures in the chalk. Locally successful Grey alder at Friston have shown some very remarkable nursing effects, and there can be very little doubt that nitrogen fixing powers of the alder roots would be very useful on chalk downs were the tree more easy to establish.

Curiously enough the Oregon alder (*A. rubra*), which has been an almost general failure in Britain, also succeeded well on the Clay-with-flints of Holt Down (see Plate 16). So far as is known, it has not been tried on shallower chalk soils.

One alder, however, has performed outstandingly well on the rendzina soil of War Down. This is the Mediterranean species, *A. cordata*, a limestone tree which appears to have lower mositure requirements than most alders. Here it has attained 45 feet in height in twenty-two years, with a mean breast height girth of 17 inches, and a total yield of 1,921 Hoppus feet per acre. This is on a fully exposed down at 650 ft. altitude, with little more than a foot of loamy soil over the upper chalk. No coniferous nurse was used. On this performance, one feels that *Alnus* *cordata* is well worth considering, particularly where the quick establishment of broadleaved cover is the main object. (See Plate 19). It is probable that this tree would have had wider trial but for the cautious attitude to alders following early disappointments.

Another of the relative successes at Queen Elizabeth Forest has been the small-leaved lime, *Tilia cordata*. On a slightly deeper soil than in the *Alnus cordata* plot, it has reached 32 feet in height in twenty-three years; again without conifer nurses. The limes are quite at home on the chalk, but are not likely to compare at all favourably in yield with beech, especially on the thinner soils. (See Plate 20).

A tree which has not been much planted so far on bare downland is wild cherry or the gean, *Prunus avium*. It is a not uncommon inhabitant of chalk woodlands. It has been noticed that it is quite a good starter on chalk, and seems less sensitive to sward competition than many broadleaved species.

Ash and sycamore, which are common constituents of chalk or other calcareous woodlands, are scarcely worth considering in the planting of bare downland. They can of course be established; both are more moisture demanding and even less tolerant of sward competition than beech, and are only likely to succeed where soils are reasonably deep and the topography provides adequate moisture supply. Wash soils on the north aspects of chalk down can sometimes be persuaded to grow respectable ash or sycamore.

The other common maple—Norway maple (*Acer platanoides*), is a great deal easier to establish on chalk downland than sycamore. Although there are several favourable mentions of it in the literature, it does not seem to have been very widely tried. It has been very successful at Friston Forest, not one of the easiest chalk environments. Atkins (1945) stresses the value of Norway maple on the Leatherhead Downs. He recommends mixing it with beech, as it starts quicker than the latter. It was considered a generally more successful species than beech on thin chalk soils at Bacombe, where a number of species have been tried (Hudson 1930). Norway maple is not likely to yield as much as beech though it may well grow rather faster for the first twenty years. Where it has been established on chalk it regenerates very freely indeed and could easily become a permanent component of chalk woodlands.

Chapter 6

PROSPECTS OF CHALK DOWNLAND PLANTATIONS

While this report is mainly concerned with the establishment of plantations, it may not be inappropriate to say something about the later growth and yield to be expected of such crops. This however can only be attempted in somewhat general terms since the chalk downland environment is extremely diverse, and we do not have sufficient examples of older plantations to cover the range of conditions. The lack is more serious for the subsidiary species than for beech.

The establishment of chalk downland plantations is frequently (though not generally) a rather slow business. In the period before the closure of canopy the young trees are subject to considerable hazards; frost, drought and exposure, troubles accentuated by the returning sward. Losses are often numerous, and young plantations are frequently irregular in stocking and development. Under these conditions it is not surprising that the form of young beech in chalk downland plantations leaves much to be desired, and only too often there will be insufficient stems of reasonable form from which to select a future crop. In the chalk downland environment everything turns on success and speed in establishment.

There is little doubt that the form of beech established on open downland is very poor compared with that planted on old chalk woodland sites, where use has been made of whatever cover is available. Where young beech crops have been successfully established, but appear to have an insufficient stocking of stems of good form, the forester is confronted with a very awkward problem. On the one hand, he will rightly dread the prospect of setting back the succession to woodland conditions by any drastic clearances; but on the other, it is not encouraging to contemplate the increment for the rest of the rotation being laid down on stems of extremely poor quality.

If the plantations are mixed, it may be possible to hold a proportion of the conifer nurse crop. This of course depends in the first place on the prospects of the conifer remaining in health, which have been discussed elsewhere. In the authors' opinion, there has been a tendency to remove conifer nurses too soon, or to remove them altogether when some could have been left. Unless there is some overmastering reason for doing so, it seems pointless to remove conifers to leave a pure beech crop of low prospects. It is usually better to thin mixed crops on their merits, removing only those conifers which are competing with beech of good stem form, or those which are dead or obviously dying.

It is sometimes assumed that when pines begin to die on chalk, all are bound to do so in the near future, and that all the pines may as well be removed in one operation. It is argued that failure to do this will mean that there are many dead and dying pines on the ground till the next prescribed thinning operation. Most foresters dislike the idea of allowing moribund pines to remain on the ground, because of the risk of building up a large population of the Pine shoot beetle (*Myelophilus piniperda*). This is sound enough, but there are circumstances where it does not much matter, there being no pine of any value in the vicinity. Even a dead pine is some use as shelter, and the first wave of deaths may leave many survivors. However, the failure (partial or general) of a nurse crop before woodland conditions have been established is a serious matter. Recultivation for planting will not usually be possible, and the conditions will be difficult for the establishment of a more suitable species. In any case, if the original nurse crop has succumbed to chlorosis, the success of an alternative conifer is somewhat problematic. Recently, *Thuja plicata* has been introduced into poorly stocked beech plantations after the failure of Scots pine nurse crops prior to the closure of canopy. This must be regarded as experimental, especially on very thin chalk soils on south facing slopes. In fact, on the most difficult downland slopes of southern aspect the partial failure of plantations tempts the forester to spend very much more money than the site is worth.

As mentioned in Chapter 4, there is some promise in the use of the herbicide 'dalapon' to control sward where other means are impracticable, and it might well be tried in this situation. It is quite clear that any effort to introduce a further subsidiary species after the failure of the first will result in much waste of money unless special care is taken in estab-

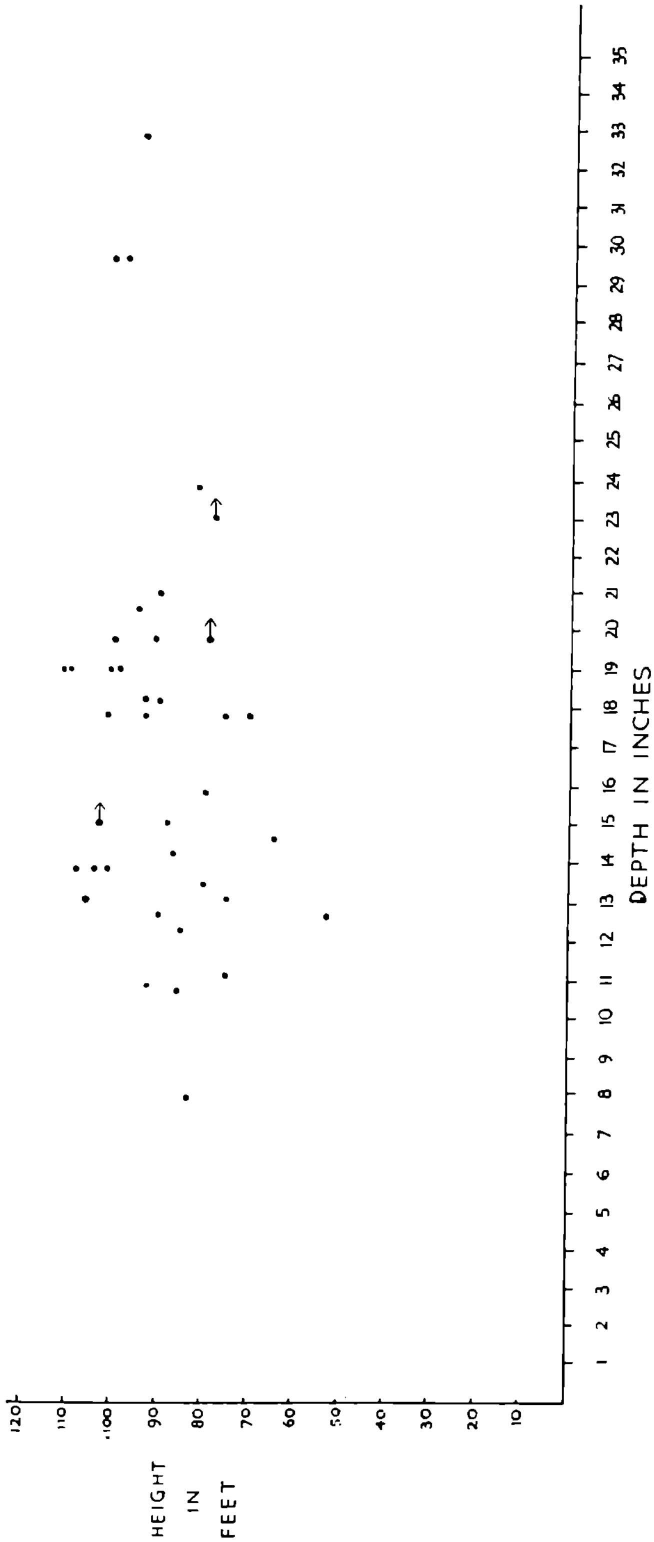

Fig. 9. Height of mature beech stands in relation to soil depth.

lishing it. When the first nurse crop has suffered from chlorosis it hardly seems advisable to attempt a conifer again; the promise of such species as *Thuja plicata* and Lawson cypress should not be overestimated. If the original beech is well established it might even be worth while planting more in tight groups wherever there are gaps. It would not be illogical to attempt certain other broadleaved species which appear to be reliable performers on chalk, such as *Alnus cordata*, *Prunus avium* and Norway maple. However, any remedial measures of this sort in struggling plantations on the thinnest soils should only be undertaken in the clear understanding that the investment is very dubious.

Difficulties in the establishment phase are likely to have a profound effect on the value, if not the yield, of chalk downland plantations. The factors influencing the growth of beech woodlands have been studied by Watt (1924), Brown (1953) and others, and special attention has been paid to the chalk as one of the most important environments for this tree. A good deal of the evidence from such studies refers to semi-natural woodlands or to plantations on old woodland sites, and if applied uncritically to bare downlands, might well give over-optimistic estimates of yield. It may however, be worth reviewing some of the evidence on the development of beech on chalk downland sites. It is generally agreed that the limiting factor to the growth of beech on the thinner rendzinas is the water supplying power of the soil. The shallowest rendzinas on steep southern and south-western slopes, where the soil may consist of a little weathered material in the interstices of chalk rubble barely covered by vegetation, are not only extremely difficult to plant, but are certain to be of very low productivity under beech (or any other species). These sites may well be considered unplantable as a purely economic proposition, though no doubt if it is necessary to establish woodland on them for shelter or other reasons, it can be done. The forester should not however delude himself that he is going to improve these sites much by establishing tree growth on them. No rapid deepending of the weathered profile need be expected, though there may be some lessening of chlorotic symptoms in beech as woodland cover is established. Fortunately we are not always dealing with shallow rendzina soils on southern aspects, nor is the rendzina general; in any case many rendzinas offer a fair depth of rooting. Undoubtedly the depth of free rooting material over the chalk is important to beech (even more so to certain other species), but there is clearly no very simple relationship. There is illustrated in Figure 9 where the height of a number of beech stands, a hundred years or more old, are plotted

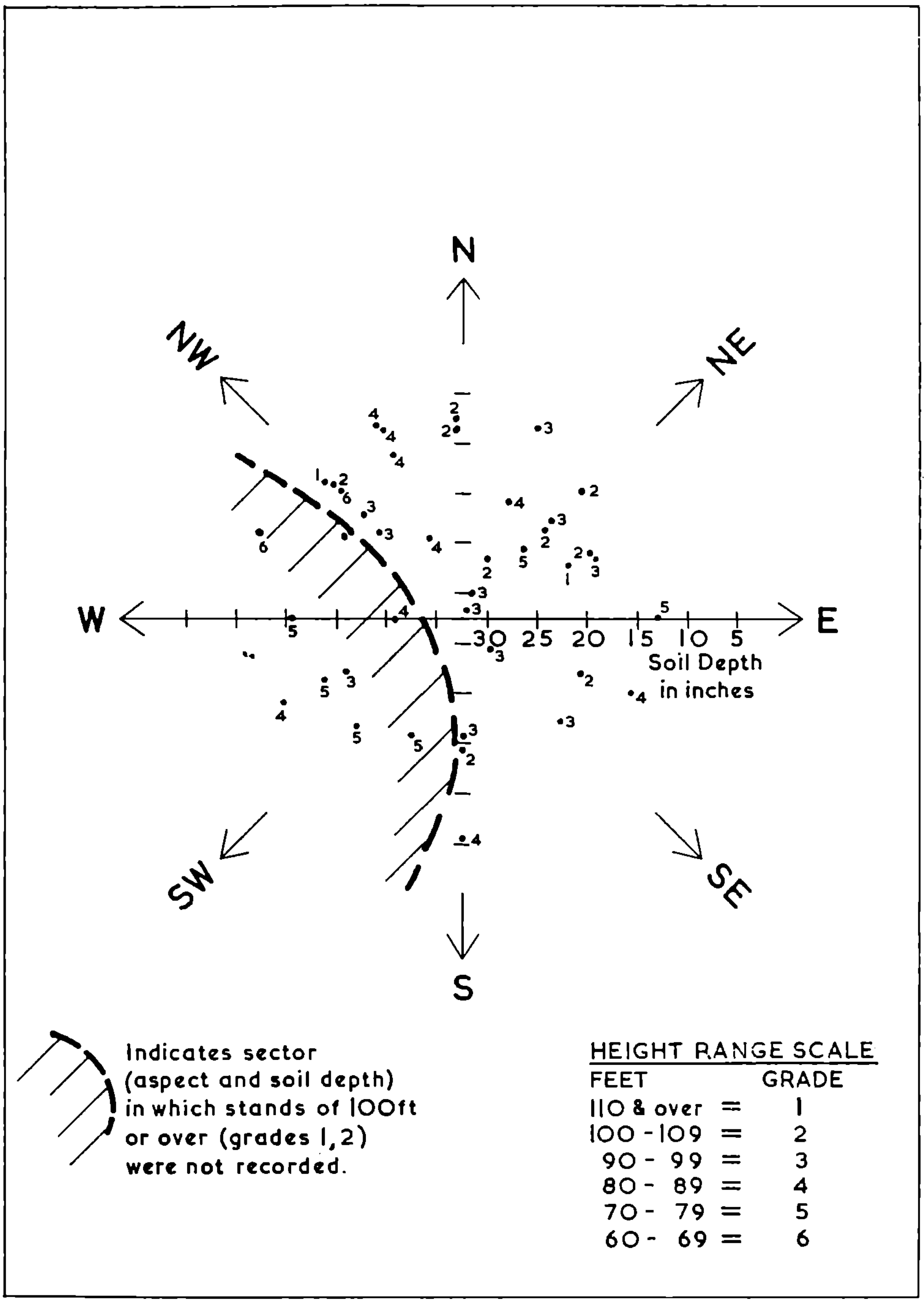

Fig. 10. Mature beech stands in relation to aspect and depth of soil.

TABLE 10: QUALITY CLASSES OF BEECH

England: Chalk substrates			*England: All Formations*		
Quality Class	I	15%	Quality Class	I	28%
„ „	II	30%	„ „	II	29%
„ „	III	27%	„ „	III	23%
„ „	IV	23%	„ „	IV	10%
Unclassed		5%	„ „	V	10%
Total		100%	Total		100%

against the depth of soil over the chalk. The measurements are due to Brown (1953).

As is only to be expected, there is some suggestion of better height growth with increasing depth of soil, but it is interesting to note how uncritical this factor seems to be over the range of soil depths represented.

The observation by Perring (1959) that the moisture axis on an isolated down runs from north-east to south-west has already been quoted. It would be expected therefore that beech would be more sensitive to the depth of soil on south-west aspects than on north-west ones. In Figure 10 records of the height growth of mature stands of beech have been plotted on a diagram which combines soil depth and aspect (the data are due to Brown). It will be noted that for the best growth of beech there is a strong suggestion that shallow soils may be adequate in the north-easterly aspects, but not in the south-west aspects. For lesser ultimate height growth, there is not so much indication of sensitivity to aspect.

Yield Tables for beech have been prepared by Waters and Christie (1958). Unfortunately, few sample plots with a long history of measurement are sited on typical chalk downland. Single measurements however have been made of a considerable number of stands. The distribution of the quality classes of some fifty stands of beech growing over chalk substrates is shown in Table 10 above, in comparison with the distribution of quality classes for all the English stands used by Waters and Christie (ibid).

There is no very strong suggestion that the Chalk formations contain a range of site quality markedly different from the general English range. However, there is little doubt that the chalk stands measured do not fairly represent the downland environment, there is some bias towards the less exposed sites and the easier soil types. Hence it would be very unsafe to guess at a quality class higher than III as a general average for beech grown on chalk downlands. According to Waters and Christie (ibid), Q.C. III beech is characterised by a mean height of thirty feet at twenty-five years, fifty-five feet at fifty years, and seventy feet at seventy-five years, when a total crop yield of 4,890 hoppus feet per acre may be expected. The mean annual increment over this period will thus have been 65 hoppus feet per acre. It should of course be noted that beech crops on chalk downlands will frequently be held back by difficulties of establishment, and height growth in the first twenty-five years may give a very pessimistic idea of future production. The differences in early rates of growth attributable to silvicultural treatment are illustrated in Fig. 7.

It has been mentioned that few, if any, other broadleaved species seem likely to yield more than beech on chalk downlands. The early performance of *Alnus cordata* at Queen Elizabeth Forest (noted in the previous chapter) is exceptional. The total yield of this plot at twenty-two years of age approximates to that of Quality Class I beech at thirty-five years of age. The alders however are shortlived trees, and it would be surprising if this rate of growth were maintained.

The yield of conifers either pure or in mixtures with beech on chalk downlands is extremely difficult to predict. Soil changes may bring about startling differences in behaviour in very short compass. The most notable effects are seen from the transition from acid deposits (even if quite shallow) to rendzinas or other soils with much free lime in the profile, such as recent washdown soils.

At the present time, Corsican pine is undoubtedly the most important conifer in Chalk downland plantations, being well suited to the climate of the Chalk regions and to the rapidly draining soils. It has also a useful degree of tolerance to calcareous soils. With an inch or two of acid soil in the profile, one would not expect any serious losses from chlorosis, and one might safely assume that a pure crop would reach small sawlog dimensions at least. If the soil is limey to the surface, and especially on dry south facing slopes or on narrow ridges, it would be unwise to expect pure plantations of Corsican pine to carry a heavy stocking for long. Deaths from chlorosis in Corsican pine are however usually less widespread than with Scots pine, often leaving a very open stand but with enough survivors for retention, perhaps with underplanting. The appearance of many of the older plantations suggests that a limited number of conifers can be carried to large timber dimensions on quite shallow soils.

If it is scarcely possible to suggest an 'average' yield for beech on chalk downlands, it is even less realistic to attempt such an estimate for conifers. Where there are a few inches of lime free soil, one would expect Corsican pine to vary in growth according to the depth of free rooting material between the rates characterised by Quality Classes I–III (*Revised Yield Tables for Conifers in Great Britain*—Hummel and Christie 1953). Extreme exposure, especially in coastal situations, will also be an adverse factor. At thirty years of age one might thus expect total yields in the range, 2,800–5,000 hoppus feet over bark. For older pure crops, yields are problematic; but it must be re-emphasised that the depth of lime free material is highly critical, and if this approaches two feet, conifers whose requirements are easily met by the general climate of the chalk regions (such as Douglas fir, Corsican and Scots pines and European larch), will not be limited by the chalk substrate in rotations of sixty years or so.

Little can be added on the subject of conifer yields from mixtures with beech. The general aim in broadleaved/conifer mixtures is to establish a fully stocked crop of hardwoods, the conifer assisting silviculturally and also providing early revenue. Interventions in the mixture are often necessary for purely silvicultural reasons and unless there is some special local market, early thinnings may be quite uneconomic. The only circumstance which is special to the chalk is that the conifer nurse may run into trouble when it is scarcely marketable, and dying nurse crops of pine may present a problem of protection from the build-up of insect populations. At the best, well arranged broadleaved/conifer mixtures may yield something over half the total yields to be expected of the conifer as a pure crop on the same site; and without diminishing the value of the broadleaved crop, early returns from which are usually quite uneconomic. This is the most favourable result possible, and will be rarely attained on the chalk.

Something may be said about certain hazards not peculiar to the chalk, but which may assume special importance on it. Beechwoods everywhere are prone to damage by the Grey squirrel, and as chalk downland plantations usually suffer from a shortage of well-formed stems further losses or serious damage can be disastrous. It is little use planting beech at all unless there are likely to be adequate control measures for Grey squirrels. The rabbit has been greatly reduced by *Myxomatosis* over most of the chalk, but it would be over optimistic to assume that this general menace to woodland management has vanished for ever.

The departure of the rabbit seems to have been accompanied by an increase in numbers of the hare, whose playful habit of nipping the tops off young plants will be familiar to most foresters. As on other predominantly grassland sites, the short-tailed field vole can reach plague numbers, and may attack beech three inches or even more in diameter.

One almost specific disease—the nutritional disorder chlorosis—has been mentioned. The most important disease at the present time in British plantations is caused by the root and stem-rotting fungus *Fomes annosus*. This is typically a fungus of basic or less acid soils, and is, for example, very prevalent in pine plantations on the shallower and more lime rich soils over the East Anglia Chalky Boulder Tills. Conifer plantations on fresh chalk downland sites may be expected to be reasonably free from *Fomes* to start with, and *Fomes* will not be of importance to nurse crops which are to be removed at the pole stage. Longer conifer rotations on chalk will almost certainly build up more serious infections, and wherever there is any likelihood that conifers will succeed conifers, it will be necessary to take preventive measures (by creosoting the stumps of all thinnings) from the outset. The disease, and recommendations for control measures are described by Low and Gladman (1960).

Appendix

NOTES ON THE PRINCIPAL EXPERIMENTAL AREAS

The two principal experimental areas are Queen Elizabeth Forest in Hampshire, and Friston Forest in Sussex.

QUEEN ELIZABETH FOREST

General

Planting commenced in 1928. The total area is just over 2,477 acres, of which 1,683 are planted. Originally known as Buriton Forest, it was re-named Queen Elizabeth Forest to commemorate the Coronation of Her Majesty.

Situated in the South Downs on the Hampshire–Sussex border, the forest lies some four miles south of Petersfield and about twelve miles north of Portsmouth at elevations ranging from 300 to 802 ft. above sea level. The majority of the land is between 400 and 700 feet, and consists of steep sided, rounded topped downs, with narrow valleys between. The main downs from west to east are:—War Down (802 ft.); Holt Down (655 ft.); Head Down (666 ft.) and Ditcham Woods (661 ft.). Near the crest of the downs the slopes are very gentle (about 1 in 15 to 1 in 40) but away from the top the slope increases rapidly, and is steepest about three quarters of the way up the sides, where the gradient is from 1 in 2 to 1 in 4, with a few slopes as sharp as 1 in 1½.

Climate

Over most of the forest the annual rainfall is about 36 inches, but no doubt over the 600 ft. contour it will reach 40 inches. The nearest station with long-term records is Ditcham House, approximately one mile east at an altitude of 550 ft., where the mean annual rainfall is 40.6 inches, and the driest months April, May and June, with averages of 2.25 inches, 2.16 inches and 2.26 inches respectively. 'Official' droughts (fifteen consecutive days to none of which is credited .01 inches of rain or more) are not common, but water shortage has undoubtedly been a serious factor in the establishment of plantations especially on shallow soils and steepish southern aspects.

The hill tops are exposed to strong winds from all quarters and exposure is an important factor affecting both the establishment and ultimate height growth of trees.

On the lower slopes of the downs, and especially in the valleys between them, spring frosts have been damaging, but on the higher ground frost has been of relatively little importance.

Geology and Soil

Queen Elizabeth Forest is wholly on the chalk, and the soils are mainly rendzinas or rendziniform, except for the well marked Clay-with-flints remnants on the peak of Holt Down and on part of the high area near Ditcham House. The upper parts of War Down and Head Down are on the Upper Chalk, and the same strata occur on Holt Down and Ditcham Woods, here capped with Clay-with-flints. Most of the remainder of the forest area is on the Middle Chalk. The typical soil of these downs is crumby, dark, loamy in texture, rich in fragments of calcium carbonate and with a variable amount of flints. Near the top of the downs the humus stained material is usually between four and nine inches deep and merges into chalky rubble with interstitial loam grading into fissured chalk at about twenty inches from the surface. On the steep slopes of the downs humus stained soil is much shallower, often only two to three inches deep. The reaction is normally between pH 7.5 and 8.0, but varies considerably, and on the flat tops may be 6.0 or even less in the top inch or so under 'chalk-heath' vegetation. In the valley bottoms the soil is usually a fairly deep light loam developed on material eroded from higher up the slopes, sometimes including flints from the upper chalk. From grey-brown at the surface, the soil becomes yellow or orange brown at about twelve inches and merges into chalky rubble at varying depths up to about forty inches.

Overlying a part of the top of Holt Down, and some of the high ground at Ditcham, are the remnants of Clay-with-flint caps, in places over 4 ft. deep but tapering out at the edges. Soils here are clay-loams, often with numerous flints, and a much lower pH of 5.5 to 6.5. At the southern end of the upper part of Holt Down, and also locally at Ditcham, an altogether different soil type occurs which may well originate from loess. This is a deep, light brown, loose, loamy soil, with some flints, and from twelve to forty inches thick overlying calcareous material. It is usually on the acid side, pH 5.0 to 6.5.

One other soil of distinct character should be mentioned—this is associated with the larger rabbit warrens, and often occurs at the junction of the Upper and Middle Chalk. It is a loose churned-up soil from $1\frac{1}{2}$ to 5 feet deep, consisting of a mixture of small chalk fragments, top soil, flints and powdery chalk. It is usually of a grey-brown colour and highly alkaline, pH 7.7 to over 8.0, and nearly always supports good growth of broadleaved trees. There is well distributed organic matter to a considerable depth.

The amount of flints at this forest is variable. They are most frequent over the outcrop of the Upper Chalk, and in the Clay-with-flints caps. Compact flint pavements are fortunately rare on this site.

Vegetation

The main vegetation type on these downs is a fairly dense grass mat consisting chiefly of *Festuca ovina* (aggr.), *Festuca rubra*, *Avena pratensis*, *Agrostis tenuis*, *Briza media*, *Anthoxanthum odoratum*, *Carex glauca*, *Koeleria cristata*, and scattered herbs such as *Leontodon hispidus*, *Lotus corniculatus*, *Carlina vulgaris*, *Cirsium acaule*, *Thymus serpyllum*, *Plantago lanceolata*, *Poterium sanguisorba* etc. On the hill tops the soil is sometimes slightly acid and *Calluna vulgaris*, with *Potentilla erecta*, may be common (for example—top of War Down.)

Where the ground has been cultivated in the past—such as a large section of the top of Holt Down—a very different vegetation is found; a mixed grass-herb type with a bewildering array of species, over fifty of which are quite common. It is very difficult to pick out the most frequent from such a multitude, but the following are very conspicuous:—*Holcus lanatus*, *Arrhenatherum elatius*, *Dactylis glomerata*, *Anthoxanthum odoratum*, *Bromus mollis*, *Briza media*, *Rubus fruticosus*, *Reseda lutea*, *Calamintha acinos*, *Centaurea nigra*, *Cirsium arvense*, *C. lanceolatum* and *C. palustre*, *Leontodon hispidus*, *Scabiosa arvensis*, *Senecio jacobaea*, *Sonchus arvensis*, *Epilobium montanum*, *Geranium dissectum*, *Linaria vulgaris*, *Lotus corniculatus*, *Lychnis alba*.

On the deeper sandy soil at the south end of Holt Down a decidedly more acid plant association covers a wide area. The main species being:—*Agrostis tenuis*, *Festuca ovina* (aggr.), *Anthoxanthum odoratum*, *Teucrium scorodonia*, *Calluna vulgaris*, *Potentilla erecta*, *Rumex acetosella*, *Rubus fruticosus*.

The Clay-with-flint areas on Holt Down and at Ditcham carry a moister vegetation, often with scrub patches of *Rubus*, *Clematis*, *Cornus*, *Crataegus*, *Virburnum*, etc. Larger grasses such as *Dactylis*, *Arrhenatherum*, *Holcus*, *Brachypodium*, etc. are frequent, and there is a very wide range of herbs such as *Epilobium*, *Aquilegia*, *Hypericum*, *Origanum*, *Euphorbia*, *Campanula*, *Fragaria*, *Asperula*, etc.

The sparsest vegetation is found on the steeper gradients just below the tops of the downs. Here cover is very thin and there may be numerous small, almost bare patches. The main species are:—*Festuca ovina* (aggr.), *Briza media*, *Thymus serpyllum*, *Asperula cynanchica*, *Carduus acaulis*, *Lotus corniculatus*, *Prunella vulgaris* and *Leontodon hispidus*.

One or two areas of natural woodland may be found on the downsides (for example—Benham's Bushes on the west flank of Holt Down). These consist of mixed yew, hawthorn, whitebeam, *Clematis*, dog rose and bramble, with a few large beech forming a higher canopy here and there.

There are two other vegetation types worthy of mention, the gorse patches, and the elder shrub on the old rabbit warrens (Plates 1 and 2). The two gorse areas on War Down were sown about 1924 for game cover and have proved most interesting from the ecological point of view. Before any tree planting was done the gorse had completely altered the normal downland flora. *Cornus sanguinea*, *Clematis vitalba* and *Rubus fruticosus*, had come in, and the herbs included *Agrimonia eupatoria*, *Cirsium arvense*, *Epilobium montanum*, *Teucrium scorodonia*, *Solanum dulcamara*, *Sonchus arvensis* and *Urtica dioica*. The main grasses were *Arrbenatherum elatius*, *Dactylis glomerata*, *Holcus lamatus*, *Festuca rubra*, and *Bromus asper* (occasional). Wherever there have been extensive old rabbit warrens an elder scrub growth has developed—often forming quite a dense canopy over small irregular shaped areas. The main species in this type are:—*Sambucus nigra*, *Clematis vitalba*, *Rosa canina*, *Crataegus monogyna*, *Rubus fruticosus*, *Bryonia dioica*, *Urtica dioica*, *Epilobium* (several species), *Teucrium scorodonia*, *Cirsium arvense*, *Holcus lanatus*, *Dactylis glomerata*.

Pests

In 1928 when the first block of the forest was enclosed, the area was alive with rabbits and it has been a constant task to keep them down, until the advent of *Myxomatosis* in 1953. Both hares and deer have also been troublesome and have caused serious damage to several experiments. Grey squirrels are a serious menace and close vigilance will be essential, especially as they constantly come in from neighbouring woods. Over the years one or two serious outbreaks of voles have done considerable damage to young beech plants and in the early years initial planting losses were also increased by moles.

Between 1928 and 1938 Ghost moth (*Hepialus humuli*) larvae killed many young beech trees during the first three or four years after planting.

There do not appear to have been any very serious fungal troubles at this forest. *Nectria ditissima* is causing a number of cankers on the beech and there is a fair amount of bacterial canker on the ash. The die-back of Scots pine at about twenty years old appears to be due to lime induced deficiency, and severe pine die-back seems more associated with free lime in the upper soil than with actual soil depth.

FRISTON FOREST

General

Planting started at Friston Forest in 1927, one year earlier than at Queen Elizabeth Forest. It has a total area of approximately 1,986 acres, of which about 1,723 are at present planted. The forest lies in Sussex at the extreme eastern end of the South Downs, about four miles west of Eastbourne and just over one mile from the sea to the south. Elevations range from 15 ft. at Brook Lane to 510 ft. at the far north-east corner of the forest, but most of the area lies between 100 and 400 ft.

The downs are flatter and the valleys much wider than at Queen Elizabeth Forest; and the topography is more complex, the land surface not being divided into well defined downs. The steepest gradients are about 1 in 3½, but most of the slopes are much more gentle, from 1 in 6 to 1 in 25. The valley bottoms and down tops are almost flat or may have a slight gradient of perhaps 1 in 35.

Climate

Mean annual rainfall at Friston waterworks, which lies within the forest area, is 32 inches—well below that of Queen Elizabeth Forest. The driest months are March, May and June, with means of 1.9, 1.7 and 1.8 inches, and droughts are decidedly more severe than at Queen Elizabeth Forest; their effects again being aggravated by slope, aspect, thin soils and competing vegetation, combined with very high sunshine values.

Friston Forest being only just over a mile from the sea, and the Cuckmere Gap giving easy access to southerly gales, exposure is a very important factor—not only on the hill tops but also in all but the most sheltered sites in the valleys. During rough weather the winds at Friston carry a great deal of salt and this has often given rise to severe damage to many tree species, especially beech and European larch (Plates 6, 7 and 8). Despite the proximity to the sea, much damage has been caused by spring frosts on the lower slopes and valley bottoms, the contours being such that the cold air draining down from the hill tops tends to get trapped in the lower areas (Plate 9).

Geology and Soil

Unlike Queen Elizabeth Forest, the Friston area lies solely on the Upper Chalk, though quite large tracts are covered with Clay-with-flints, and Valley Gravels cover some of the low ground. Although many of the soils are rendzina or rendziniform, there is a much larger area of heavy loam over Clay-with-flints than occurs at Queen Elizabeth Forest, and a far greater proportion of the ground has at one time or another been under cultivation.

The rendzina soils present the same typical dark, crumby loamy appearance as at Queen Elizabeth Forest but are, on the whole, a little thicker at Friston, and the chalk rubble subsoil is rather less compact. In some places, however, on slopes where past cultivation has taken place, there has been considerable erosion, and here the soil may be very thin indeed and tree growth extremely poor. Between Charlston Bottom and Old Barn there is a large area of fine friable light loam, sometimes with a few flints, often ten to fifteen inches deep. This is a very similar soil to the light loamy type at Queen Elizabeth Forest towards the south end of Holt Down. The loose churned up soil associated with the larger rabbit warrens is also present and shows roughly the same characters at both forests.

Lastly, mention should be made of the patch of brown earth of high base status in the extreme south-east corner of the forest, on high ground adjoining the Eastbourne road, where there is an usually good plot of sycamore. This is a loam, fairly heavy in the lower layers, from 2 to 3 ft. deep with very few small flints; it is one of the best soils in the forest and probably derives from a thick loess deposit.

Vegetation

A fairly full description of the vegetation at Queen Elizabeth Forest has been given, and as Friston is geologically very similar, it may be sufficient to point out the main differences in the vegetation between the two forests. The most striking thing is that over more than half of the Friston area the dominant grass is *Bromus erectus*, whereas at Queen Elizabeth Forest it is very rare. This most conspicuous distinction is probably due to some disturbance, such as grazing, having practically eliminated the *Bromus* in the latter area. Where rabbits have been very numerous at Friston the *Festuca* grasses have become dominant, the *Bromus* has died out, and the sward is very similar to the common type at Queen Elizabeth Forest.

The second major difference between the two forests is that at Friston there are a few hawthorn scrub areas, but none of the well developed yew-Whitebeam-hawthorn woodland types that occur at Queen Elizabeth Forest. Another point of interest is that *Calluna vulgaris* is common in certain areas at Queen Elizabeth, but *Erica cinerea* is only an occasional rarity. At Friston, the exact reverse is the case.

Several other differences may be mentioned briefly. Dwarf thistle, thyme, squinancy wort, and several other plants, particularly associated with a short herbage, are comparatively rare at Friston. *Scabiosa columbaria* and *Plantago media* are common at Queen Elizabeth Forest, but are mainly replaced at Friston by *Scabiosa arvensis* and *Plantago lanceolata. Avena pratensis* and *Avena pubescens* are much more frequent at Queen Elizabeth Forest than at Friston, while *Festuca elatior arundinacea* is rare at the former but locally common at the latter forest. There are much larger areas of natural gorse (*Ulex europeaus*) at Friston, but Hemp agrimony (*Eupatorium cannabinum*) is much more frequent at Queen Elizabeth Forest. Similar elder scrub thickets occur on the larger rabbit warrens at each forest.

Before leaving the subject of vegetation, it may be noted that the grass mat formed by *Festuca* species is far denser and more harmful than the mat associated with *Bromus erectus*, and in this respect newly planted trees are better off over a large part of the Friston area than they are over much of Queen Elizabeth Forest.

Pests

As at Queen Elizabeth Forest, the great trouble at Friston in the early days was the rabbit; the downs were positively alive with them. Hares, deer and voles have also given trouble from time to time. An unexpected difficulty in some early experiments with direct sowings of common broom was the large number of slugs and snails which played havoc with the newly germinated seedlings. *Nectria* canker on beech is present but has not yet been reported as serious. As at Queen Elizabeth Forest, pine die-back is associated with lime-induced chlorosis, especially on soils having free lime in the upper layers.

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