Forestry Commission

Bulletin 78

Natural Regeneration of Broadleaves

J Evans

Forestry Commission Bulletin 78

Natural Regeneration of Broadleaves

J. Evans
Principal Silviculturist (South),
Forestry Commission

LONDON: HER MAJESTY'S STATIONERY OFFICE

First published 1988

ISBN 0 11 710263 6

ODC 231 : 174.7 : 61 : (410)

Keywords: Natural Regeneration, Broadleaves, Forestry

Enquiries relating to this publication should be addressed to the Technical Publications Officer, Forestry Commission, Forest Research Station, Alice Holt Lodge, Wrecclesham, Farnham, Surrey GU10 4LH

FRONT COVER: Natural regeneration under a stand of *c.* 150-year-old beech in the Chiltern Hills. (*10244*)

Contents

	Page
Acknowledgements	4
Preface	5
Chapter 1 **Introduction**	7
Chapter 2 **Use of natural regeneration**	11
Chapter 3 **Preparing for natural regeneration**	20
Chapter 4 **Regeneration operations in the stand**	26
Chapter 5 **Protection and care of young regeneration**	29
Chapter 6 **Advance regeneration, recruiting coppice regrowth, and suckers**	36
Chapter 7 **Notes on natural regeneration by species**	38
Glossary	43
References	44

Acknowledgements

Several people have helped in the course of preparing this Bulletin about natural regeneration. Visits to John Workman's estate, Ebworth, are always stimulating as one sees his successes with beech regeneration and I remain indebted to him for many ideas and thoughts and for kindly reviewing a draft of this Bulletin. Similarly, during frequent visits to the Forest of Dean, the deputy surveyors Tony Joslin and John Everard have more than willingly discussed in detail the minutiae of oak regeneration. Also, attendance at Institute of Chartered Foresters' regional meetings, mainly of Wessex and South East groups, has provided both sites and forums for discussion of regeneration.

Dr Colin Tubbs and his publishers, Collins, kindly gave permission for reproduction of Figure 3.2.

Within the Forestry Commission Ken Buswell and B. P. Easton furnished data at short notice and Ken Baker, in his inimitable way, kept the writer informed of oak regeneration experiments using treeshelters and led him safely to Wistman's Wood.

All photographs in the text were taken by the writer; George Gate developed and printed them. Line drawings were prepared by John Williams. The Library at Alice Holt Lodge was as helpful as always.

Preface

Natural regeneration holds a special fascination yet in formal forest management, aside from some medieval systems, it has never featured strongly in Britain. Impressive broadleaved forests in France and Germany, based on natural regeneration silviculture, have made British foresters sometimes desire to emulate such achievements as, perhaps, the epitome of good forestry practice. Yet the appropriateness or relevance of such silviculture to much of our forestry is debatable. Nevertheless, natural regeneration should perhaps play a wider role on the grounds of amenity, conservation and, in some instances, as genuinely the least costly method of establishment. The *Guidelines for the management of broadleaved woodland* and the *Woodland Grant Scheme* booklets both encourage natural regeneration as well as planting. This account reviews experience with broadleaved species and, where possible, recommends practices to follow.

Few foresters have concerned themselves with natural regeneration but in writing this Bulletin I would want to single out some who have contributed greatly to our understanding and experience. They include the writings, in the first half of this century, of Ray Bourne, R.S. Troup and A.S. Watt; and, more recently, the work of that enthusiastic forester the late Morley Penistan; Eustace Jones' definitive accounts of species and his studies of oak regeneration in the New Forest; and today's practitioners Ted Garfitt, Rodney Helliwell, Tony Joslin, and John Workman.

Chapter 1
Introduction

Natural regeneration can broadly be defined as raising a forest crop without resorting to planting, direct sowing or coppicing. It is the random nature of exactly where young trees spring up on a site and sometimes of the species which grow that marks out natural regeneration, not freedom from man's influence. Indeed, many naturally regenerated stands are highly artificial, being the result of frequent intervention before, during and after the regeneration phase to achieve specific well-defined ends.

The bulk of natural regeneration concerns raising high forest from seed directly from parent trees. Occasionally stems arising from sucker growth or recruited by singling and storing coppice shoots are a useful supplement to growth from seed or an appropriate system in their own right. They are mentioned briefly.

Natural Regeneration in Britain and Western Europe

As a formal management system natural regeneration has been surprisingly little used in Britain. Evelyn (1665) discusses coppicing, planting and sowing, but makes almost no reference to the subject; similar appeals to rebuild the nation's forest estate were wholly directed to planting, e.g. Pontey (1808). Evidence of this can be traced in many old forests, where perhaps natural regeneration might have prevailed, such as Alice Holt, the New and Dean forests, where the great majority of the prime oaks now standing were planted or sown often in mixture with other species including pine (Joslin, 1982; Small, 1982). Medieval Britain was dominated by coppices (often with standards), wood pastures and hunting forests, not by managed high forest raised through natural regeneration. Where natural regeneration did arise it was less by design and more a response to changing browsing pressure – see Figure 5.2. from Tubbs' (1986) work in the New Forest relating graphically tree age-classes and deer/pony numbers.

In the present century natural regeneration has remained largely neglected (Bourne, 1945) or a subject of conflicting advice – Cotterell (1950) discourages use of virtually any ash regeneration, Helliwell (1981) rather the reverse. There have, of course, been some successes such as with oak in the 1930s at Salisbury Trench, South Bentley, and Bick Kiln in the New Forest, group regeneration of beech in parts of the Chilterns and at Ebworth in the Cotswolds, of oak at Grizedale, and Garfitt's (1963) work with ash at Cirencester Park are all representative. An account of current examples in Britain will be found in Pryor and Savill (1986). The earlier use of the word 'successes' perhaps implies many failures. This, in fact, is not true, in that there have been few attempts at controlled natural regeneration, and is more a reflection that the system is seen as a vague ideal rather than widely applicable to British forestry.

The one exception to this picture of infrequent natural regeneration is informal colonisation – successional woodland (Peterken, 1981) – whether birch on heathland, sycamore and ash in old quarries and roadside verges, or oak in rough pasture and scrub just outside the woodland boundary. This natural process has added significantly to woodland cover in Britain and, where allowed to develop, can be brought into productive use.

Overall, however, the contrast with the continent is striking. The superiority of natural regeneration over planting is a basic tenet of French and German silviculture (Everard, 1986; Joyce and Gardiner, 1986). It is still ardently encouraged for broadleaved species (Schrotter, 1978) though recourse to planting to fill gaps is now begun sooner than in the past. Nevertheless, generations of British foresters will continue to visit Europe and come away impressed by the success of the system applied over millions of hectares of oak and beech forest, e.g. Evans (1982) and Penistan (1960). As is well-known, much forest management in Europe is directed at securing satisfactory natural regeneration, and an array of silvicultural systems has arisen, tailored to different species and site requirements; they were recorded systematically by Troup (1928) in his book on the subject.

Current Interest

Matthews (1986), in an important review of irregular forestry practice, distinguishes two periods this century in attitudes to natural regeneration. Up to the 1950s British foresters were largely content to study the potential usefulness of natural regeneration systems and application of continental methods; the primary task occupying most attention was afforestation of generally inhospitable upland sites. Since about 1950 increasingly widespread attempts have been made to apply group selection systems, frequently to rehabilitate unproductive woodland such as arose from wartime fellings, but also as a specific management policy, e.g. in the woodlands of the National Trust, for reasons of amenity and visual impact (Wright, 1982). To this, today, may also be added conservation. In general, Peterken (1981) includes natural regeneration as one of the strategic principles which encourage conservation values in woodland and, indeed, expects foresters to make use of it when it occurs. Specifically, there is the special case of upland woods of native species, possibly relicts of Britain's natural forest cover, which are almost invariably heavily browsed and largely devoid of regeneration, such as in many Welsh oakwoods (Goodier and Ball, 1974; Kirby, 1982; Smith, 1983; and Towler, 1980).

Two silvicultural reasons have also brought natural regeneration, especially of broadleaved species, to the fore: (1) the ability to cope with small areas, of any size, through advances in individual tree protection and hence the removal of the inordinate cost burden of conventional fencing in such cases; and (2), on former woodland sites, the recognition of the value of spontaneous regeneration as side shelter for planted trees and as a supplementary source of potential crop species.

The attraction of potential cost saving, as a stimulus to natural regeneration silviculture, is unclear. Certainly, where natural regeneration comes with little assistance and the dominant species is well suited to the site, some saving should result, the main expenses confined to timely cleanings and removal of any overstorey (Figure 1.1). Where management specifically aims for natural regeneration – preparation (and subsequent handling) of the overstorey, preparing the ground, and care of regeneration – along with timing of timber sales dictated by the seed crop rather than the market, it will rarely be substantially cheaper than clear felling and replanting.

Natural regeneration is eligible for grant support under the Woodland Grant Scheme which, along with the considerations just noted, is likely to lead to this form of silviculture playing a greater role in British forestry practice. The scheme offers grant aid both for new natural regeneration and for existing regeneration under 20 years of age. During the first 18 months following the former Broadleaved Woodland Grant Scheme's launch the Forestry Commission received over 5000 applications. These contain proposals to regenerate by natural means almost 900 ha of woodlands and to manage a further 360 ha of regenerated woodlands under 20 years of age. Twenty per cent of these areas are in ancient semi-natural woodlands.

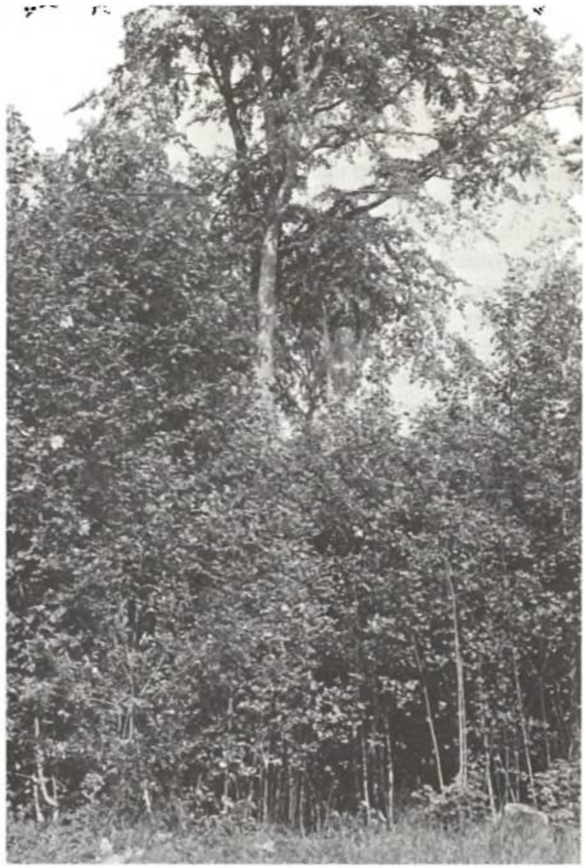

Figure 1.1 Dense sycamore regeneration aged 15 years, with a small proportion of beech and an occasional ash, beneath 150-year-old beech standing at 20 stems per hectare. The regeneration is in urgent need of respacing. (Sussex.)

Perceived Obstacles

A number of factors have created a reluctance in Britain to pursue natural regeneration methods. It is useful to list the main ones and, in doing so, to dispel the aura of mystery about the subject.

1. *Need for great skill and art.* Many writers have intimated or stressed this. To quote an early authority (Somerville, 1891) "When it is resolved to renew a wood by natural seeding, all efforts must be directed towards providing conditions which will be likely to bring about a successful result . . . The impediments which obstruct the path to the

successful formation of woods by means of selfsown seed are so great . . . My conviction is that our (British) foresters should very seldom indeed aim at a hard and fast system of natural regeneration, but while making use of all serviceable advance growth, should depend on artificial planting . . . as the mainstay of British silviculture." Without doubt patience and commitment are needed – natural regeneration is not synonymous with *laissez-faire* management (Pryor and Savill, 1986) – but whether Somerville's strident warning and discouragement is valid will, at least it is hoped in part, be dispelled by this Bulletin.

2. *Infrequent seed production.* Only beech and oak have infrequent seed years, and only beech really long intervals of sometimes 10 years or more between heavy mast years; other important broadleaves generally seed freely in most years. This infrequency is mainly a problem when seeking to tie forest management to a rigid timetable and tends to be viewed as a shortcoming more by those used to conventional plantation forestry rather than those practising natural regeneration. If committed to natural regeneration one either waits for plentiful advance growth, i.e. to follow the regeneration, or prepares the stand and ground by judicious thinning in readiness for the good year when it comes, and then felling. If neither approach is feasible or hoped-for regeneration fails, then one can simply fell and replant. There is nothing so special about the system that it has to be slavishly followed regardless of circumstance except, perhaps, where preservation of rare or ecologically important genetic stock is uppermost.

3. *Specific objections or fears such as the failure of oak to regenerate, especially under its own canopy, and the unreliability of ash regeneration.* These are two frequently heard comments, in part true but not to the point that oak cannot be grown under oak or that all ash growth must be rejected. To quote Shaw (1974) "The case for reproductive failure of oak is therefore rejected as totally unsupported by the available evidence . . . The only real threat to oak, in Britain, is over-grazing and over-browsing."

Figure 1.2 No sign of natural regeneration under New Forest oak in ancient and ornamental woodland open to browsing and grazing by ponies and deer. *(A10894)*

4. *Complexity of continental silvicultural systems.* As mentioned, these arose to meet particular situations and most are not applicable to Britain. For example, the absence of silver fir forests or other extremely shade tolerant species rule out any possibility of true selection systems. Equally, the ability to copy the impressive uniform shelterwood systems of France will be confined by sheer scale to large forests, by the need for a high quality parent crop, by availability of suitable sites to avoid significant exposure and high risk of windthrow, and by an owner's circumstances to allow income to be spread over many years. Continental practices should not be a model, as British conditions are different, but only an example.
5. *Failure of any sign of regeneration in many mature and over-mature woodlands* (Figure 1.2). Except in the case of very old trees in decline which are producing little seed, this is very largely a question of protecting against browsing and grazing, taking steps to prevent such damage, and coping with dense weed growth, especially on moist or fertile sites.

Chapter 2
Use of Natural Regeneration

Natural regeneration is simply one way that the succeeding forest crop is formed. It can be planned or unplanned, accepted or discarded but, while never likely to become in Britain the kind of formal system so widely adopted in Europe, there are many situations, in addition to places where it is actively sought, where it may be used or where its occurrence must be considered in the overall silvicultural treatment of a stand.

Use of Natural Regeneration in Existing High Forest

In high forest in Britain the occurrence of natural regeneration is probably more frequent than our predominantly plantation orientated forestry might suggest. In the course of management it may arise spontaneously or by design, i.e. as an object of the silvicultural system employed. The following notes consider both its formal and informal use and how best to handle it in practice. Figure 2.1 shows diagrammatically the principal silvicultural systems employing natural regeneration.

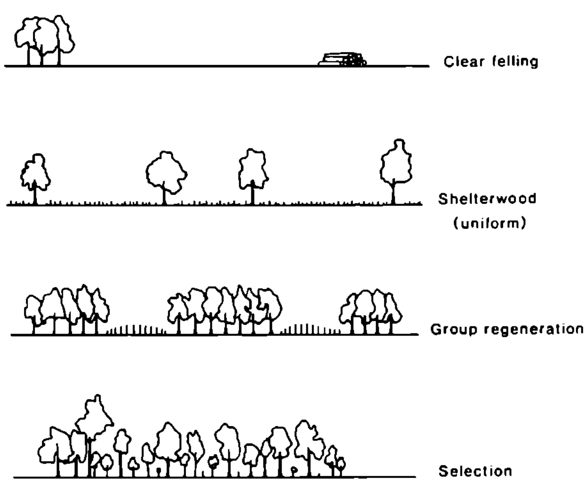

Figure 2.1 Diagrammatic representation of the main natural regeneration systems.

Largely because natural regeneration has been little used in Britain, the economics of the system have rarely been investigated and there are few direct comparisons with planting. Superficially, restocking ground without having to resort to planting is clearly attractive. And, under favourable conditions of plentiful regeneration on suitable sites, natural regeneration offers the potential of reduced establishment costs. Crockford *et al.* (1987) cite group regeneration of beech, birch colonisation of open ground, and use of shelterwood systems to regenerate ash and sycamore, as situations where natural regeneration can lead to savings in establishment. They estimate that the reduced expenditure by not planting is not altogether offset by increased costs of initial ground preparation, respacing and cleaning operations. Pryor and Savill (1986), in an earlier report of the work, suggest establishment by replanting is nearly twice as expensive as the combined costs of cultivation, weeding and cleaning involved in natural regeneration.

It is difficult to assert categorically that natural regeneration will necessarily be cheaper than planting. There remain the imponderables with natural regeneration of denied opportunity to change species, of felling operations determined by seed production potential in a particular year rather than the market, and sometimes a prolonging of the regeneration phase. The Woodland Grant Scheme recognises that, overall, major savings are unlikely to accrue and both planting and natural regeneration attract the same level of support.

Clear felling

Clear felling and replanting is the principal method of regeneration of broadleaved woodlands in Britain. Nevertheless, it is observed from time to time, perhaps where planting has been delayed, that natural regeneration develops profusely after a site is cleared (Figure 2.2). This can happen with all the main broadleaved species but is particularly common with ash, sycamore, birch and willow. Seed already deposited on the site or brought or blown in from adjacent stands is the source of the new crop.

Such restocking after clear felling can be used to considerable advantage but as a formal system of regeneration there are several problems: (1) it is unpredictable and cannot be relied on unless there are signs of advance regeneration; (2) the species which arise may be neither what is wanted nor the same as the previous crop; and (3) it is rare to achieve even

Figure 2.2 Seven-year-old natural regeneration, mainly of oak and birch with some hornbeam coppice, which arose unplanned following clear felling of the previous oak stand. Initially the regeneration was neglected but it has now been cleaned and respaced to release oak stems; a good stand is in the making.

moderate stocking over areas much larger than about one hectare. However, if such regeneration can generally be expected and management is flexible enough to 'wait and see' there are two distinct possibilities of using it. First, there may be sufficient trees of final crop potential that a worthwhile stand can be encouraged by judicious weeding and cleaning; any gaps can usually be made good by accepting and singling suitable coppice regrowth. Secondly, the woody regeneration can be used to provide side shelter for a planted crop, especially important when planting at wide (3 m) spacing or when small numbers of trees are used for enrichment scattered over a large area.

Shelterwood

Shelterwood is where an overstorey or parent crop is managed to bring about regeneration on the ground beneath. The uniform shelterwood system is much the commonest in Europe, where an even-aged regeneration is sought over the whole compartment, though there are many variants employing the general principles of shelterwood silviculture, i.e. a scattering of parent trees over a site to provide the seed for the next crop. As a system its specific object is to achieve natural regeneration, and that principally of the overstorey rather than from some other seed source, of reasonably uniform age class over a whole compartment.

In Britain the shelterwood system has been little used for many reasons though there is no doubt that under the right conditions it can succeed with oak and beech. The bulk of Chapters 3 and 4 which follow describe how to encourage it and to show what influences natural regeneration when it is specifically sought, in the course of either shelterwood or group regeneration systems (p.13).

Selection system

The selection system also depends on natural regeneration to perpetuate the stand and, in its strict form, involves managing a compartment so that in all parts there is a complete age range present of seedlings, saplings, pole-stage trees, and semi-mature and mature ones. New seedlings must continually augment the young crop and must be very shade tolerant since they are never completely opened up but always in the shade of older trees. Although appearing 'natural' and perhaps the forester's fancied ideal, as Peterken (1981) points out it is highly artificial and unnatural; Europe's ancient wildwood mostly consisted of 'patchy even-agedness'. True selection forestry is practised and finds its best expression in the strongly shade bearing silver fir forests of Switzerland, where continous ground cover is essential on the steep mountain slopes, but is probably unworkable in Britain apart from, possibly, with beech. This might be worth trying since Koop and Hilgen (1987) found that, in a protected, largely undisturbed, forest reserve mainly of beech near Fontainbleau, even small, one hectare plots contain beech trees of all sizes with very few pioneer species.

Group systems

Group regeneration involves working with several small areas of 0.1 to 0.5 ha (Figure 2.3) in a stand which is to be regenerated, waiting until they are making good progress say after 5 to 10 years, and then further opening up existing groups and starting new ones, when seed or advance regeneration is plentiful, and repeating the cycle until the whole compartment is regenerated over 20 to 40 years. As Pryor and Savill (1986) emphasise it is not so much a silvicultural system in its own right but a variant, and an important one, of either clear felling, shelterwood or selection forestry. Rather than attempting to regenerate a whole compartment at one time, work is concentrated in several small parts or groups. Apart from clear felling, it is probably the most widely used system in Britain in the lowlands (Matthews, 1986) and is suited to the complex needs of many upland woods (Smith, 1983).

Figure 2.3 Group regeneration in the New Forest.

Group systems have many landscape and amenity advantages but require skill and commitment over a long period to complete regeneration of a compartment. The group system approach is probably the most appropriate to attempt when seeking to carry out natural regeneration in Britain since it does not depend on just one good mast year but allows a gradual regeneration process following 'nature'. Of course, working is not concentrated in the same way as clear felling but provided coupes are of the size indicated (> 0.1 ha) and because there are usually several such coupes in the compartment being worked, a marketable quantity of timber will result. As a guide, the minimum size of opening for group regeneration should have a diameter of at least twice the height of adjacent trees.

Other systems

The more formal high forest systems have been outlined but quite frequently, especially in lowland woods, regeneration can spring up in gaps or on exposed edges. When dense, such regeneration in the case of ash, for example, often survives better than planted trees (Helliwell, 1981) and can be recruited into the woodland. Opportunistic use of treeshelters can, of course, more or less ensure good establishment of sufficient trees and of the preferred species in mixed regeneration.

Colonisation of Open or Waste Ground

Throughout Britain wherever land, though not previously wooded, is enclosed and protected from heavy grazing and browsing, woody growth will soon develop. Indeed, many areas of scrub, particularly on the Downs, can be attributed to the temporary reduction in rabbit populations by myxomatosis in the late 1950s and 1960s. Colonisation can be rapid and in only

Figure 2.4 Vigorous woody regrowth on abandoned allotments beside railway – birches, sallows and willows, alder, sycamore and a few oak.

Figure 2.5 Young ash and oak occurring naturally on a roadside embankment. (*A10897*)

a few years pasture, abandoned arable land or waste or derelict ground can become covered in 'scrub' typically of hawthorn, birches, willow species and oak. Peterken (1981) gives many examples of such recent secondary woodland, though probably the best known are Broadbalk Wilderness, at Rothamsted, where cereal cultivation stopped in 1881 and the land left to develop naturally ever since and, in the New Forest, the expansion of woodland cover, mainly of birch and oak, at the forest edge on to adjacent heath. Small (1982) cites a figure of 517 ha added to the forest area since the 1880s. Also many commons have progressed from open grass to woodland this century.

Such colonisation is not only confined to the more undisturbed environment of the countryside but occurs wherever land is disused (Figure 2.4) – railway embankments, road-side verges (Figure 2.5), old mineral workings, spoil heaps, etc. In the uplands, provided browsing pressures are reduced, birch and rowan colonisation of rough grazing and moorland will occur.

The extent of such woodland is not easily quantified. Locke (1962) suggested that between the mid-1930s and 1960 perhaps 16 000 ha of this secondary woodland had developed in southern parts of Britain. And, in the 1980 Census of Woodlands (Forestry Commission, 1982), the evidence that the total area of broadleaved woodland was little different from that in 1947, despite the widespread conversion of broadleaved woodland to conifer plantation in the period immediately after the Second World War, suggests it amounts to tens of thousands of hectares.

The great bulk of such natural colonisation has the potential to develop into high forest and add to the woodland estate. It can be used as a matrix of shelter into which trees can be planted or its composition and stocking can be augmented by enrichment planting; but as virtually a free gift, apart from the opportunity foregone in not planting or using the land in some other way, even unimproved woodland represents a welcome addition of often considerable potential both to the forester and conservationist. Older regeneration, even if not of a desired species, can be heavily thinned and used to provide dappled shade for a few years to give protection from frost, sun-scorch and exposure to an underplanted crop. This is a considerable aid to establishment for many broadleaves, but notably beech and southern beech.

Unplanned Regeneration in Plantations

Broadleaved crops

Frequently when broadleaved crops are planted some natural regeneration also appears. This is especially common on former woodland sites. Marketable species can always be used to advantage to make good any gaps in the planted stand but where such regeneration is mainly of willow species or birch its role should generally be confined to initial nursing followed by removal during cleaning operations where it is a serious threat to main crop trees.

As has been stressed above there are many benefits to be had in using scrub woodland of mixed regeneration into which the main crop of broadleaves is planted; both Harley (1982) and Joslin (1982) advocate this approach to establishing broadleaves.

Conifer crops

In coniferous plantations the appearance of broadleaved species poses different questions. A common sight on hillsides in the uplands is vigorous growth of birches, rowan, sycamore and willows in young spruce and Douglas fir plantations, especially on second rotation sites, which outgrow the conifers (Figure 2.6). This can also occur in lowland pine crops. Such a broadleaved component within a stand, along with the common ride and stream side trees and shrubs, is a generally welcome addition for amenity and conservation but occasionally can be a threat to achieving a full stocking of conifers. Unless more than ten per cent of a crop is seriously at risk it is probably better to ignore such regeneration and accept it as an enhancement adding diversity. Where large parts of a stand are at risk of becoming swamped some cleaning may be called for. If neglected, not only will the present conifer crop become poorly stocked but its subsequent replacement will be more difficult.

Figure 2.6 Birch and sallow begining to dominate a poorly stocked spruce plantation. (*A10895*)

Landscape and Amenity

Woodland which appears natural has widespread public appeal. The apparent absence of man's influence, though a mistaken belief, makes naturally regenerated woodland more attractive. There is a greater diversity of structure, stocking, and species than associated with planted woodland and, as a silvicultural system, it is likely to have popular support as a more 'natural' component of the countryside.

Within the uplands natural regeneration, especially of broadleaved species, can soften harsh edges, enhance topographic features and generally break up the monotony of large blocks of conifers.

Role in Conservation

Using natural regeneration brings many conservation benefits. Peterken (1981) includes it as principle 10 to adopt in good woodland conservation and makes the following points:

1. it favours native species;
2. it favours the species already on the site;
3. it tends to generate mixed stands;
4. the stands produced tend to have a more irregular structure than plantations;
5. the natural genetic variety can be better maintained; and
6. the natural distribution of tree species in relation to soil types is favoured with the whole habitat better preserved.

Of course, natural regeneration is a disadvantage where aggressive species are a threat, of which rhododendron is amongst the worst. The question of sycamore is much less clear. A carpet of dense young sycamore apparently invading a woodland (e.g. Figure 7.3) rarely results in development of anything approaching pure sycamore stands (Taylor, 1982).

In general, where the principal aims are conservation or amenity, natural regeneration of woody species should be encouraged. Among planted trees it should only be removed where it is a real interference, not because of a desire for tidiness.

Figure 2.7 Poorly stocked upland wood open to sheep grazing with little prospect of natural regeneration in its present condition. *(A10893)*

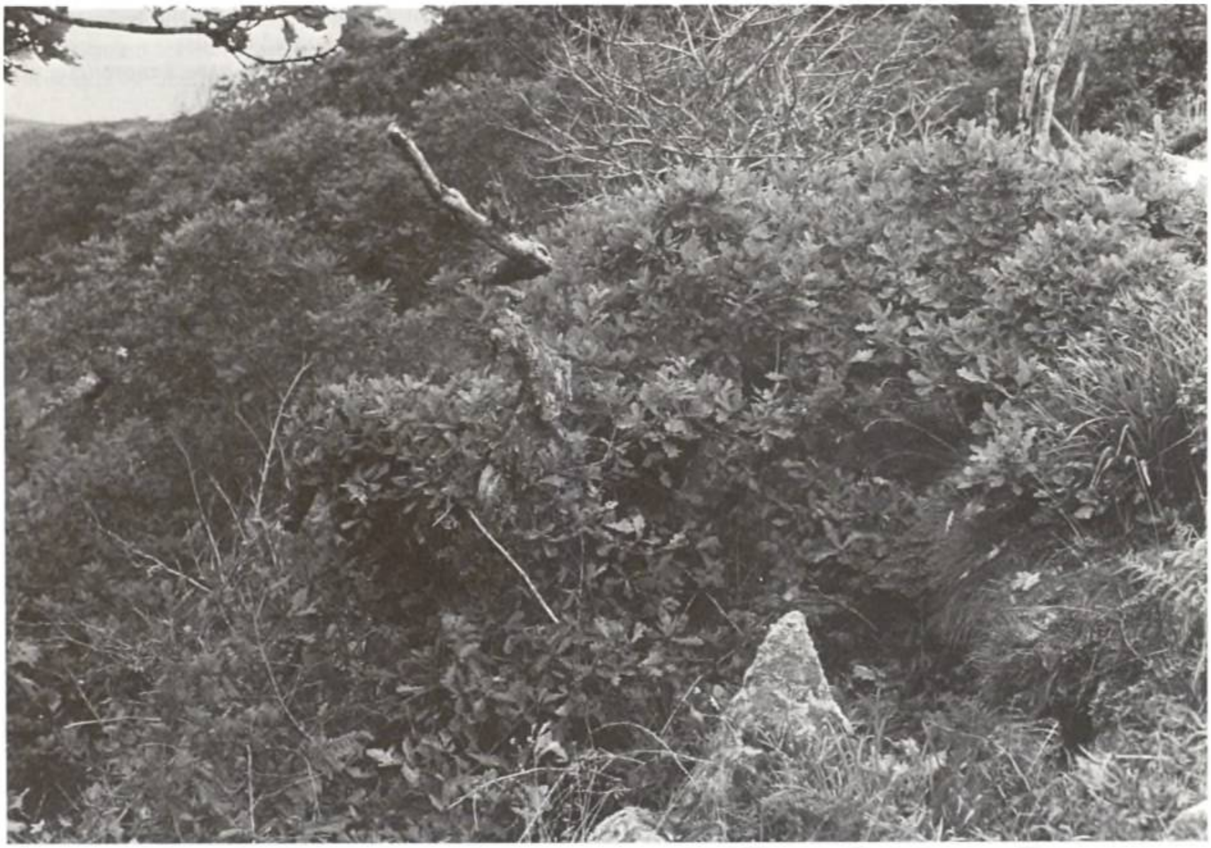

Figure 2.8 Oak 'coppice' from repeated browsing and oak seedlings at edge of Wistman's Wood, Dartmoor. The wood has expanded by about one hectare this century as browsing pressure has declined. (*A10892*)

Natural Regeneration in the Uplands

Natural regeneration of broadleaves, though perhaps thought of as a lowland phenomenon, is highly pertinent to the uplands and not only because birch and rowan spring up profusely on any exposed mineral soil and heath. Many semi-natural woodlands in the uplands are failing to regenerate and gradually disappearing because of grazing pressures (Smith, 1983; Towler, 1980) – see Figure 2.7.

Allaby (1983) suggests natural regeneration is probably the most economical way of maintaining woodland in inaccessible locations, and on steep and rocky slopes.

The dominant influence of grazing, mainly by sheep and red deer, in preventing regeneration is demonstrated by the regrowth that follows whenever it is removed or sharply declines. Even a woodland as unpromising a source of regeneration as Wistman's, Wood in Devon, at 400–420 m elevation on Dartmoor, and consisting of scrub oaks known never to have been taller than 6 m for the last 300 years, has expanded by natural processes in the present century (Figure 2.8) owing to reduced populations of sheep on the moor (Proctor *et al.*, 1980).

The occurrence of natural regeneration of broadleaves in the uplands brings some advantages. It is a safer means of increasing the proportion of broadleaves than by planting since it comes from locally adapted stock and, necessarily, where it survives it must be able to grow despite the harsh conditions. The upland environment is generally less well suited to broadleaves than the lowlands, so that building on nature's provision appears a sensible course, especially since there is rarely any intention of growing high quality timber crops.

Practical Application – When to Use Natural Regeneration

1. When it is available, natural regeneration can be used for:
   a. infilling gaps;
   b. addition to woodland;
   c. stocking inaccessible pockets of ground;
   d. enhancing wildlife and conservation interest in plantations;
   e. occasionally restocking a clear felling where it comes up in profusion unexpectedly; and
   f. regeneration operations when a heavy seed year coincides with harvesting.

2. Use natural regeneration only when conditions are right:
   a. there is a good parent crop well suited to the site;
   b. the ground is not overrun with weeds or likely to prove difficult to handle, such as being very damp or with deep accumulations of organic matter;
   c. there is flexibility in forest management to time operations with good seed years, or follow advance regeneration; and
   d. there is the skill and patience to oversee such silviculture.

3. Use natural regeneration to aid conservation and amenity objectives.

Chapter 3
Preparing for Natural Regeneration

Where it is decided to use natural regeneration as the means to re-establish a forest stand, two preparatory measures will improve the chances of success: ensuring (1) a plentiful seed supply and (2) ground conditions which will favour germination and survival.

The Stand

Where production of timber is the main object of management, natural regeneration should only be pursued if the parent crop is of good quality and is well suited to the site. Good stem form and a history of satisfactory growth are important but not the only criteria. In the case of oak both criteria are frequently found on sandier soils but these sites are generally prone to shake in timber and, if on felling the defect affects a significant proportion of the trees, perpetuating an oak crop is of doubtful value. Similarly, sites associated with pink coloration in beech, blackheart in ash, vein in cherry, etc., may be better growing another species, especially since it is not known to what degree these defects are inherited. It is better not to risk perpetuating them.

Reproductive maturity

Most species produce plentiful seed for a substantial part of their life but both in the years leading up to reproductive maturity and when trees become very old, seed yields may be small or negligible. Table 3.1 shows seed production characteristics for the principal broadleaved species.

Crown development

To achieve the best quality timber crop only the best parent trees should be a seed source. Thinnings late in the life of a stand will favour such trees as a matter of course, but where natural regeneration is planned thinning should also encourage development of large, even partially isolated crowns, on the most desirable mother trees. Both the larger volume of crown and its greater exposure tend to increase flowering and thus seed bearing capacity. However, later thinnings are often of the 'low' type concerned mainly with removing the poorest and most defective stems, therefore, where natural regeneration is planned, an element of

Table 3.1 Seed production of broadleaved trees in Britain

Species	Minimum seed-bearing age (years)	Interval between large seed crops (years)	Age after which seed production begins to decline (years)	Time of seed-fall or seed dispersal (months)
Alder (Common)	15–25	2–3	—	Sept.–Mar.
Ash	20–30	3–5	80	Sept.–Mar.
Beech	50–60	5–15	160	Sept.–Nov.
Birch	15	1–3	60	Aug.–Jan.
Cherry	10	1–3	—	July–Aug.
Hornbeam	10–30	2–4	—	Nov.–Apr.
Lime (Small-leaved)	20–30	2–3	—	Sept.–Nov.
Norway maple	25–30	1–3	—	Oct.–Feb
Oak				
Pedunculate	40–50	3–6	140	Nov.
Sessile	40–50	2–5	140	Nov.
Sweet chestnut	30–40	1–4	60	Oct.–Nov.
Sycamore	25–30	1–3	70	Sept.–Oct.

Note: Both rapidly growing trees and ones of coppice origin tend to bear seed earlier than shown. Decline in seed production is not a sudden event and heavy crops can occur, though with longer intervals in between, well past 200 years of age for oak and beech.

crown thinning in a stand must be retained towards the end of the rotation. Preparing stands in this way is normal procedure in France and Germany and has long been recognised as an important prerequisite even in Britain (Boulger, 1907; Bourne, 1942).

Seed production

Table 3.1 provides information about seed production by species and several texts report species' phenological characteristics, including flowering and fruiting, e.g. Laidlaw (1960), Newbold and Goldsmith (1981), and in the notes about individual species in Chapter 7. Forestry Commission Bulletin 59 (Gordon and Rowe, 1982) provides a detailed account of all aspects of seed biology, formation, collection and treatment and data are tabulated by species. Matthews (1963) reviewed the factors which affect seed production.

The quantity of ripe seed produced in any one year is amongst the most unpredictable of silvicultural phenomena; many factors can affect it but the question of seed predation and mast years, critical to the practice of natural regeneration, is considered separately. There is no doubt that during the long period trees are reproductively mature, weather conditions are probably the most important influence determining seed yields from year to year. The number of flower buds is influenced by conditions when they form in the previous year, such as a warm July favouring heavy oak flowering the following May. When flowers emerge heavy rain, high winds or frosts can do damage physically and prevent satisfactory pollination, while warm summers are required for many species, especially exotic ones, to ripen fruits, e.g. sweet chestnut and walnut.

Other factors of importance are:

1. tree health, though where a tree is in rapid decline seed production may temporarily rise as a stress response;
2. defoliation by insects; and
3. period since previous heavy seed production – stem carbohydrate reserves are depleted by heavy seeding and may take several years to replenish.

Figure 3.1 Good beech regeneration at Ebworth, Gloucestershire, from the 1976 mast year.

It is this array of potential problems that deters attempts at natural regeneration and encourages recourse to the safety of restocking by planting. However, knowing there is uncertainty and adjusting management attitudes accordingly, there is no prima-facie case for abandoning natural regeneration. All broadleaved species produce many heavy seed crops (mast years) during the period they are reproductively mature; the question therefore is not so much whether but only when?

Mast years

From time to time conditions combine to favour very heavy seed crops and some years become famous for the quantities of mast produced. (The term 'mast' comes from the Scandinavian word 'mat' meaning animal fodder and relates back to the time swine were fattened on acorns and beech nuts.) In France, 1949 is considered the mast year of the century and many crops were successfully regenerated from that year's heavy seed fall. In Britain important mast years are listed by Matthews (1963). For beech the years 1911, 1921, and 1945 have passed into forest lore, for oak 1919, and even for ash, which seeds freely and frequently, 1939 and 1945 were noted for their phenomenal crops. More recently 1965 was good for beech and, not surprisingly, 1976 produced heavy seed crops on both oak species and beech (Figure 3.1); 1980 and 1984 have also been well above average and 1987 exceptional for beech in some parts and good for oak.

Clearly, the long interval that can elapse between mast years rules out relying only on such exceptional years, though obviously when they occur the opportunity must be taken to use the plentiful seed. Partial mast years with heavier than average seed crops occur at more regular intervals as indicated in Table 3.1. Natural regeneration operations, both for shelterwood and group systems, should be concentrated on these and the mast years.

Assessment of seed crop

A reasonably good indication of the developing seed crop of most broadleaves can be made by the end of June, exceptions are the later, July flowering lime and sweet chestnut. Confirmation that, for example, beech nuts are full must await later examination in October. Developing crops of all large seeded or large fruited species, oak, beech, ash, cherry, sycamore and sweet chestnut, are readily seen with binoculars from ground level. Other general indications can also be looked for to show how widespread or gregarious heavy seeding is such as the olive hue imparted by beech mast to the crown's general appearance, clusters of acorns on fallen twigs and bundles of ash 'keys' hanging from every branch. Apart from experience to judge whether a seed crop looks heavy, signs of fruit or seed on *most* branches and *the bulk* of trees of the species in the neighbourhood can be taken as a general indication. One word of caution is that prolific seeding can occur, for example, in valley stands and not ones on hilltops owing to frost or vice versa, thus it is important to inspect the whole of a stand planned for regeneration.

The current seed crop should provide the bulk of seed for intended regeneration, but where natural regeneration has been planned and prepared for over many years there will often be some accumulation of buried seed in the soil from previous years. Advance regeneration is a sign of this but when regeneration operations begin and the stand is opened up seedlings developing from the current year's crop may be augmented from these earlier seedfalls. This is a particular feature with ash, the seed of which is often dormant for 18 months and only germinates in the second year after falling.

Seed dispersal

The timing of seed fall and dispersal mechanisms obviously plays an important role in the success of regeneration. Neither can be influenced by the forester – all he must do is to provide the right conditions for the seed where it finally settles to survive and germinate (see later) – but the forester must distinguish, in planning his regeneration, between species where seed can be dispersed long distances by wind and those heavier seeded ones where most of it falls beneath or close to the parent tree.

Seed dispersed by wind over considerable distances tend to be small, light and winged or feathered, typically >50 000 seeds per kilogramme, and produced in large quantities. The main broadleaved species concerned include alders, birches, poplars including aspen, and willows. These species can colonise suitable sites far from parent trees, hence their frequent occurrence, especially birches, alders and willows, on almost all forest sites. The species are rarely regenerated in their own right as an object of management but they can, as suggested in Chapter 2, provide side shelter, a woody matrix for enriching, or dappled shade to protect underplanting. In successional terms they are colonisers preceding other high forest species.

Seeds of ash, sycamore and lime, though large, are partly dispersed by wind owing to their wings and may be distributed some way beyond the tree's natural spread. However, seeds or fruits of Britain's other principal broadleaved high forest species including oak, beech, sweet chestnut and wild cherry, are heavy and mostly fall to the ground near the parent tree. In either case, when seeking to regenerate stands naturally, sufficient parent trees of the desired species must be distributed over the site to yield a reasonably uniform scattering of seed. Although birds and many mammals will disperse large seeds long distances they cannot be relied on to stock ground remote from parent trees though they do account for some colonisation of land adjacent to a wood such as the occasional oaks springing up in grassland or a hawthorn thicket far beyond the woodland edge.

Seed falls mostly in late summer and autumn, but see Table 3.1.

Seed predation and other losses

Some seed can be lost while still on the tree. This may be caused, for example, by weevils in beech nuts, by knopper gall damage to acorns, by larval feeding *(Pseudo-argyotoza conwayana)* of ash, and by crossbill predation on sycamore, but most losses occur once seed has fallen. Oak, beech and ash seed is eaten by rodents (woodmice and voles), grey squirrels, and many birds such as jays, wood pigeons and chaffinches. Such predation can be very heavy. Shaw (1968) reported predation rates of acorns of 200 kg ha^{-1}, with wood pigeons and small mammals together sometimes destroying up to 99 per cent of the crop. It is difficult to prevent such losses though Bourne (1945) reports much reduced predation right next to human habitation, greatly increased levels 50 to 200 m away, and normal levels beyond about 400 m. He concludes that if special protection is given to exposed seed in selected areas of regeneration, abnormally high destruction can be expected nearby. If predation of seed by mice is excessively high, as may occur in beech woodland, warfarin-baited cut wheat in a hopper will reduce mice numbers. However, this is expensive as baiting points are needed every 20 m and the bait replenished regularly throughout the winter. It should only be considered a last resort and not used where there are sporting, conservation or amenity interests.

Seed which is quickly covered by litter suffers far less predation and also is at less risk from damage by sharp frosts in the autumn. Frost heave can expose buried seed, and exceptional frost and cold can shrivel beech nuts (Bourne, 1945) though adequate protection is generally afforded if there is an overstorey. Usually wet conditions may increase rotting of seed and Wardle (1957) reports this as commonly killing ash seed during the 18 months it often lies dormant.

The Ground

Requirements for seed germination and early growth

Of many thousands of seed which fall, generally only a few will germinate and survive. First, the seed itself must not be eaten nor allowed to dry out or become waterlogged and rot. Secondly, when the radicle emerges, early contact with mineral soil allows rooting into a medium with generally a good water holding capacity.

Ideal conditions are for seed to fall on the surface of slightly disturbed mineral soil and become rapidly covered by litter. Deeply buried seed germinates poorly (Shaw, 1968) while unprotected seed on the surface suffers predation and readily dries out. Seed which falls on to matted vegetation or a deep layer of accumulated litter may experience favourable conditions for germination but die subsequently from desiccation where the radicle has been unable to reach mineral soil. Also, under thick vegetation, the heavy shade and dampness expose newly germinating seedlings to damping off and mould diseases and they soon die.

These highly sensitive responses explain the variation in regeneration success observed over a site, for ash for example (van Miegroet *et al.*, 1981), and the difficulty of timing seedfall to coincide with optimum ground and soil conditions so critical for success with beech (Bourne, 1945).

Condition of soil

Physical, and to a lesser extent chemical, condition of the soil will influence natural regeneration. Dry and dusty or hard, compacted surfaces, waterlogged conditions, especially with free water at the surface, and eroding soils and other mobile substrates are mostly unfavourable for germination except, perhaps, where soil movement results in burying and hiding big seeds. Species show some variation according to soil reaction, with oak, ash and sycamore regenerating profusely on base rich soils close to neutral. Poorer regeneration, of oak for example on strongly acid soils, may be as much due to the inhospitable environment of deep litter, which frequently accumulates under strongly mor-forming conditions, as to any inherent unsuitability of soils of low pH, since Aldhous (1972) reports that most broadleaves, except for poplar and ash, grow well on acid (pH 4.5–5.5) nursery soils.

However, the main effect of soil conditions on regeneration is indirectly via its influence on ground flora. Indeed, in many situations soil conditions, such as wetness or induration, influence the quantity, and certainly the variety, of ground flora as least as much as the overstorey canopy.

Weed flora

The optimum condition is for the soil to be bare, yet moist and not eroding or compacted, though a light scattering of vegetation, particularly under beech on acid sites, will hold litter and promote soil activity. Presence of much herbaceous or grass weed growth introduces many obstacles to regeneration.

1. Weeds affect accumulation and distribution of litter.
2. Weeds shade seedlings – a carpet of dog's mercury, despite indicating a suitable ash site, can completely smother ash seedlings and prevent them from emerging (Rackham, 1980; Wardle, 1957), similarly really dense bracken is inimical to almost all species apart, possibly, from beech (Koop and Hilgen, 1987).
3. Dense grass harbours mice and voles which prey on seed and cotyledons of young seedlings.
4. Dense weed growth generally, but especially grass and patches of nettles, is a strong competitor for moisture and, probably to a lesser extent, nutrients.

Weeds can sometimes assist regeneration where they provide protection for seedlings from browsing. Oak commonly comes up through brambles and in thorn thickets for this reason.

Manipulation of shade cast by the overstorey canopy is important in control of weeds. The canopy must not be so opened up in the preparatory thinnings and fellings as to allow an influx of weeds. If this occurs one solution is to permit light grazing to browse vegetation and, incidentally, tread in seeds, especially acorns (Joslin, 1982).

In France most stands of oak are managed to encourage an understorey of hornbeam or beech specifically to suppress surface vegetation as well as to shade stems in order to discourage epicormic development (Figure 3.2). This understorey is cleared prior to seeding fellings; it must neither interfere with seed fall nor be a seed source of unwanted species nor become a competitor to the regeneration when the overstorey is opened up.

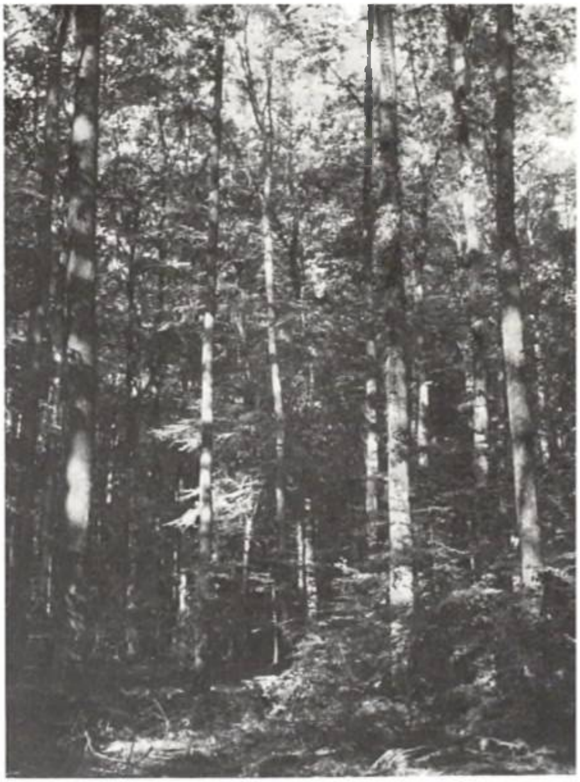

Figure 3.2 Understorey of beech and hornbeam in fine stand of oak in northern France. One of the first operations in readiness for beginning natural regeneration will be to clear the undergrowth. (*J. Evans*)

Preparing the ground

It will be clear that two conditions will greatly favour chances of regeneration: (1) exposure of loosened, mineral soil as a seedbed; (2) absence of rank vegetation. Achieving these in the autumn of a good seed year is crucial to success.

In France and Germany soil is often mechanically rotovated, scarified or disc ploughed in the summer or early autumn to prepare the seedbed, incorporate litter and humus, and dislodge vegetation. In Britain, this has occasionally been practised, e.g. on the Harpenden estate in the 1960s, and is presently the subject of trials in the Forest of Dean. For small areas of regeneration less sophisticated methods have worked well. A coarse yew log covered with branch stubs was successfully used by Garfitt (1983) at Cirencester Park to regenerate ash; sometimes the extraction of the previous crop's logs provides sufficient disturbance; the judicious use of livestock, as mentioned above, and the time-honoured practice of pannage where pigs rooting for mast and fungi turn over the soil and tread in much seed, all have their place. Even badgers may function rather like pigs in some areas.

When seed has fallen but remains mostly exposed, a scarification or brief introduction of livestock will often be enough to cover sufficient quantities. If disc ploughing is planned it should be done at this time (seed fall) in the autumn to break up the surface and fold in the seed such as acorns.

Practical Application – Preparation for Natural Regeneration

1. Prepare the stand well in advance for natural regeneration so that the best trees are likely to bear most seed.
2. Carry out natural regeneration operations only following a good seed year.
3. Ensure the ground is in a receptive condition with few weeds.
4. Scarify or disc plough at the time of or immediately following seed fall.

Chapter 4
Regeneration Operations in the Stand

Timing

Markets and season

Opportunities for successful natural regeneration are infrequent and it is difficult to time fellings to coincide with peaks in demand for timber. However, fellings of broadleaves made in the autumn after or as seed falls – the ideal for natural regeneration – will generally attract above average prices since there is often a seasonal shortage of timber as many owners delay starting to fell until February after pheasant shooting is over (Venables, 1988).

Seed years

As mentioned in the previous chapter, both oak and beech yield seed infrequently. Natural regeneration of these species must take advantage of heavy seed years. A commitment to begin fellings must be made, ground preparation to encourage regeneration carried out, and the operations followed through, following expectation of a good seed crop.

Handling the Overstorey

Considerations of light

The overstorey is one means of controlling weed growth through the degree of shade cast and root competition. Where a clear felling regeneration system is followed, the main consideration is to ensure that the preparatory thinnings in the preceding decades, undertaken to encourage crown development of the best trees, have not been so heavy that substantial weed invasion has been allowed. Where some overwood is maintained after the main regeneration fellings to provide frost protection or possibly further seed, such cover will also help suppress weeds but retention of too many trees will also slow progress of the regeneration. Here is the dilemma in conventional shelterwood systems and is succinctly put by Brown (1960):

> 'The forester's task in the ensuing years is, besides ensuring rabbits are destroyed or kept out, to increase the light reaching the seedlings without fostering the ground vegetation excessively. On some moist retentive soils it is well nigh impossible to strike a balance between loss of most of the regeneration under dense shade and the encouragement of a smothering ground vegetation by the opening of the canopy'.

With group systems most regeneration occurs in the better light conditions of the north side of the gap. This demonstrates the fact that though many species can tolerate low light levels (a few per cent of full daylight) when seedlings, including ash, oak and beech, they are *not* obligate shade demanders. Other things being equal, the more light the better the growth; indeed for all species, but notably ash, a rapidly rising level of light is needed for satisfactory development. However, maximising light supply has to be balanced by the need to retain a degree of overhead cover in some regeneration systems to protect seedlings from frost and sun-scorch, to suppress weed development, and perhaps to provide additional seed.

Selecting trees to fell

In group and clear felling systems all trees are felled in the area concerned. Gap diameter for group regeneration should be at least equal to twice the height of adjacent trees. In both systems, nearby trees of unwanted species such as birches and willows may additionally be removed to lessen seed supply.

In shelterwood systems, the main felling – called seeding felling in France and Germany – occurring in the autumn of a good seed year, should remove 50 to 70 per cent of trees in a stand, provided it has been prepared for natural regeneration in the preceding thinnings. (Where advantage is taken of a good seed year to gamble on natural regeneration without having originally planned to do so, the proportion of trees removed may differ from this percentage.) For oak and ash, sufficient trees should be felled to leave at least 6 m between crowns of the remainder, i.e. to leave about 20–25 trees per hectare, for beech rather more can be left with a 4 m gap between crowns acceptable. Unless further seed is hoped for, the trees left need not be the best in the stand. It is more important to leave an even scattering over the site.

Subsequent fellings

In both group and shelterwood systems further fellings will be required and the timing of these is critical; neglect, even for 2 or 3 years, can seriously harm progress of the regeneration.

In the group system, enlargement of the group by felling trees around the edge is essential after 4 to 5 years. Up to this point the amount of open sky will have gradually diminished since the original felling, due to crown enlargement, and the regeneration becomes increasingly shaded. Selection of trees to be removed must depend on silvicultural judgement and amount of shade being cast, but clearly there remains the need to initiate sufficient groups to assemble a worthwhile parcel of logs from the stand. New groups are opened when the next good seed year occurs.

The rate of removal of trees in shelterwood systems depends on species. For ash regeneration, all overstorey trees should be removed within 3 years, for oak in 5 to 7 years, perhaps in two operations, and for beech the work can be spread out over 15 or even 20 years if required (Figure 4.1). In Britain, since worthwhile quantities of further seed to supplement regeneration will rarely be forthcoming, except for ash and sycamore, removal of remaining overstorey trees should be dictated by their role in frost protection and diminishing weed growth and, of course, considerations of amenity where these are important.

Felling Operations

Extraction of logs in initial regeneration fellings should be all over the site, rather than chanelled to certain tracks, to minimise compaction and maximise soil disturbance overall. Opportunity should be taken where possible to extract through patches of weeds and other unwanted growth. Further scarification of the site in ways suggested in the previous chapter may be needed.

All fellings should be completed before the end of March after seedfall. Where there is advance regeneration or in the later fellings for group enlargement or removal of overstorey in shelterwood systems, felling should not be done in very cold frosty weather when the young brittle stems of the regeneration will easily snap. The direction of felling for trees where there is regeneration on the ground should generally be into weed infested areas or very densely stocked parts of the site where damage can most easily be accepted. In general, it is surpising how little damage results from such fellings. Of course, this recommendation on felling direction should not jeopardise the well-being of the tree being felled. Large crowned broadleaves require great care and should not be felled on to a large limb or rock or across a gully which stresses the stem often causing splits and cracks. One does not want to sacrifice the previous 150 years' silviculture for a small advantage for the next!

Figure 4.1 Well-established beech regeneration, 3–4 m tall. Final felling of overstorey is now due.

Practical Application

1. Felling in the autumn, just after seed fall, is ideal but must be done before the end of March at the latest. Fell trees into weed infested areas. When regeneration is present fell into dense patches but do not fell at all in very frosty weather.
2. Generally extract logs all over a site to aid scarifying except on heavy clays and other poorly draining soils where extraction should be concentrated along as few routes as possible to minimise compaction and other soil damange.
3. Gap diameter for group regeneration should be at least equal to twice the height of adjacent trees.

4. In shelterwood systems remove 50–70 per cent of the trees when commencing regeneration to leave about 20–30 trees per hectare and ensure that there is at least 6 m between crowns of remaining trees (4 m is acceptable for beech).

5. In group and shelterwood systems the timing of further fellings is critical, neglect can ruin promising regeneration. Further fellings must be made within 5 years.

Chapter 5
Protection and Care of Young Regeneration

Regeneration Losses

Background

Not infrequently a carpet of seedlings develops following a good seed year (the famous 'brosse' in French oak woods or the 'buchensalat' of German beech woods) only to disappear almost to nothing within a few years. Even with much less profuse regeneration steady attrition of numbers is common; Proctor *et al.* (1980) report from the unpromising site of Wistman's Wood that "After the 1976 good mast year 16 first year seedlings were found in autumn 1977 but a year later 10 had gone". Many factors can cause such losses after a promising start and each is considered separately.

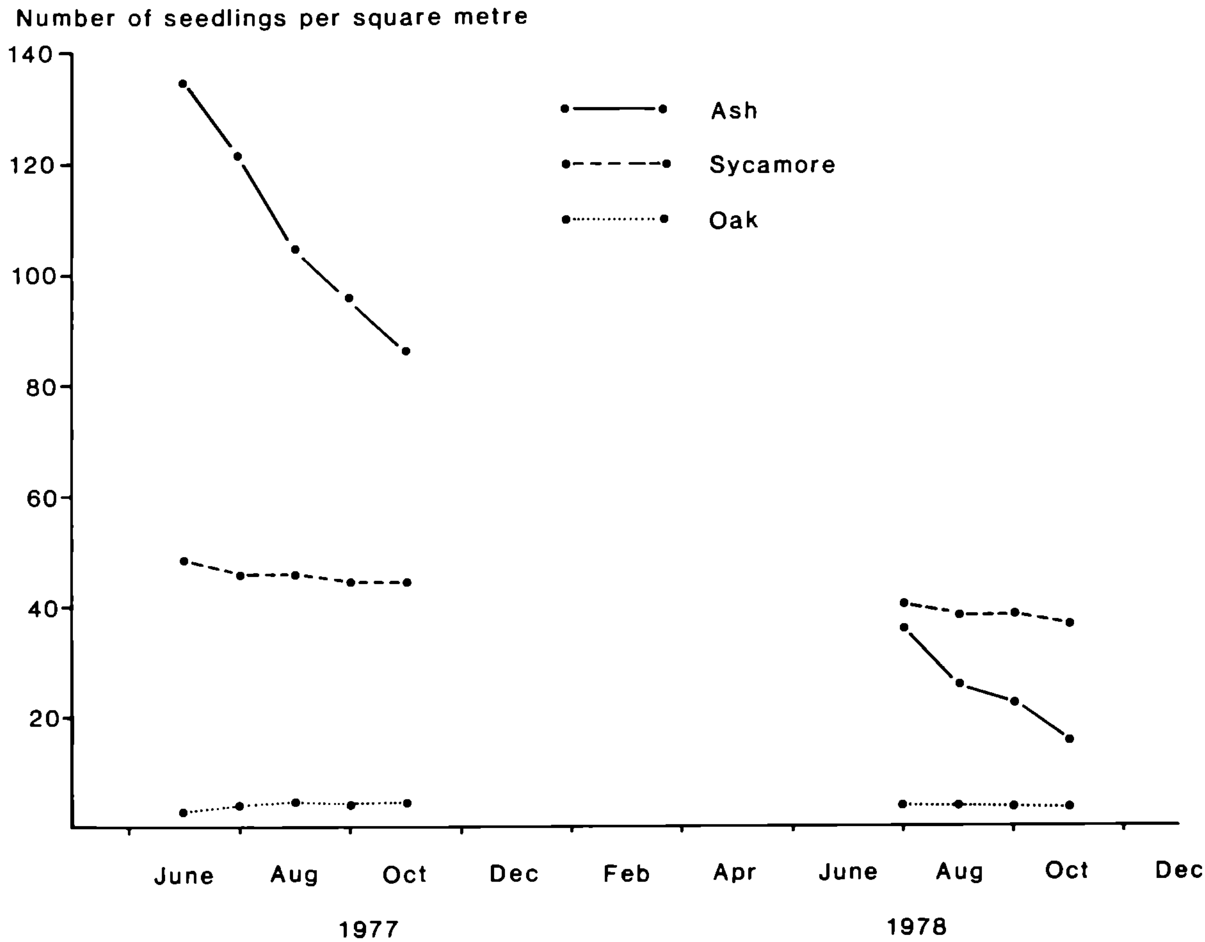

Figure 5.1 Average density of seedlings for first 2 years after heavy seedfall (modified from van Miegroet *et al.*, 1981).

Typically, dense regeneration covering the ground, whether of oak, ash, beech or sycamore can amount initially to 300 or more seedlings per square metre. Commonly, densities are down to 100 per square metre by mid-season. This general effect is illustrated in Figure 5.1, derived from van Miegroet *et al.* (1981), which shows density of ash, sycamore and oak seedlings which developed spontaneously in spring 1977 in a semi-natural stand consisting mostly of oak, some ash, and a few sycamore with several other species, and standing at about 500 stems per hectare. It shows well the inequality between species in loss of seedlings (in this instance inability to survive under a dense canopy) with a rapid fall in numbers of ash, including heavy losses in the first winter, and the almost negligible decline in sycamore. The oak data suggest recruitment of regeneration, from seed other than the initial (1976) seed fall, perhaps from buried seed or from seed produced in 1977. Van Miegroet *et al.* summarise four conclusions from the first two years of observations: a general and quick reduction of the number of seedlings; unequal resistance of species to reduction; low level of additional regeneration; and high degree of spatial variation (over the site).

Climatic damage

Late spring frost is a major cause of mortality in newly emerged regeneration. Much regeneration first appears in late April and early May and, where exposed, is very susceptible. Beech in the cotyledon or two leaf stage is at its most sensitive to frost while ash is well-known for being so, especially since seedlings can even appear several weeks before the species' frost tender foliage generally flushes in late May or early June. Frost damage is lethal in these first weeks of the growing season because the plant has used embryo reserves in germination and emergence with little available to replenish frost-damaged leaves. One general exception to this is oak which, though its foliage is as susceptible as that of other species, appears rarely killed by frost alone; certainly in Germany late frost is never considered to be lethal to oak regeneration (Otto, 1987). Nevertheless, the benefit of some overhead shelter for natural regeneration is evident. Aspect will also affect damage risk; north and north-west facing slopes are found least at risk (Bourne, 1945) owing to these cooler aspects possibly delaying emergence by a week or two.

Frost heave can also cause high mortality. Miles (1973) reports heave causing 94 per cent losses in birch regeneration during the first winter.

The other major climatic hazard is drought particularly in the late spring/early summer period as roots become established. Seedlings germinating in litter or other poorly water-retentive substrates quickly desiccate and succumb.

Birds

Many birds will peck tender seedlings, especially as cotyledons open, but pigeons are probably the most generally destructive. Ground game including pheasants can also be responsible for considerable losses.

Mammals

Browsing by small mammals, rabbits, deer, and domestic livestock probably constitute the most widespread threat to regeneration. There is no doubt that complete failure of regeneration in many upland woods is due to uncontrolled sheep grazing (Shaw, 1982; Smith, 1983) but rabbits and even slug damage are important. In the lowlands, rabbits and deer are the principal agencies today and exclusion can show dramatic effects e.g. as reported by McNeill (1945). In ancient woodlands browsing pressure can have persisted for centuries but inevitably intensity has varied and cohorts of regeneration can develop reflecting periods when damage was at a minimum. Tubbs (1986) has shown this for the New Forest where variation in pony/deer/cattle numbers can be related to age classes of regeneration; this is illustrated in Figure 5.2. He developed a weighted average system (grazing units) to describe the relative grazing pressure of different proportions of these animals together and indicates that 0.16 grazing units per hectare is the critical level in the New Forest; below this level regeneration is possible.

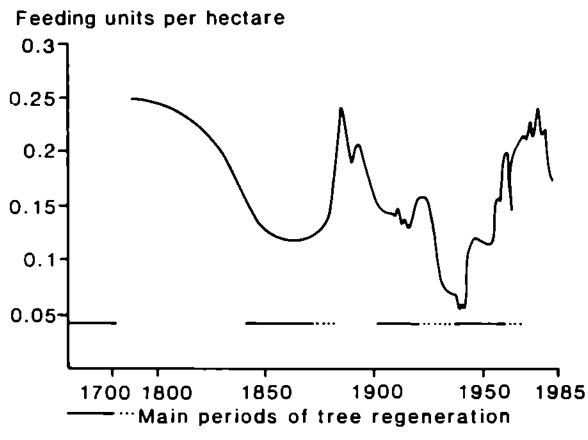

Figure 5.2 Grazing and browsing pressure and tree regeneration phases in the New Forest. (Reproduced by kind permission from Tubbs (1986) – Fig. 20.)

Browsing is not always lethal. Light browsing can control weed growth and allow copious regeneration, for example, of ash (Helliwell, 1981). Also, browsing back of oak in winter and early spring before flushing is much less damaging than defoliation, being little different from the operation of stumping back which specifically encourages vigorous shoot growth drawing on large reserves in the root.

However, there is no doubt that as a general rule every effort should be made to eliminate browsing damage where natural regeneration is sought.

Weed growth

Natural regeneration mostly occurs, of course, on former woodland sites where herbaceous weeds and woody regrowth are abundant. Compared with growth of tree seedlings, weeds, especially annuals, are very vigorous and in a few weeks can overtop and heavily shade any regeneration. Even a low growing species such as dog's mercury, where it carpets the ground, will prevent ash developing, dense nettle patches can be as harmful for beech and thick stands of bracken for oak, for example. Bramble and thorn thickets are less damaging and may even appear to favour regeneration, especially of ash and oak, mainly through the measure of protection from browsing they confer. Indeed, citing a 17th century recommendation, Flower (1980) suggests that in the past such thickets were specifically used to supplement natural regeneration by sowing acorns and ash keys among them:

> 'caste acornes and ashe keys into the straglinge and dispersed bushes; which, as experience proveth, will growe up, sheltered by the bushes, unto suche perfection as shall yelde times to come good supplie of timber.'

Weeds compete for moisture and nutrients, as well as casting shade and causing physical damage, and this root competition, including that of the often prodigious coppice regrowth from cut stumps, can be severe. In addition to this external competition there is also competition between seedlings themselves when in high numbers, and overcrowding leads to spindly, etiolated growth.

Nevertheless, it is the imbalance between weed and seedling growth and the risk of complete loss of regeneration that leads to such pains being taken to control weed development – not allowing it to get established before commencing regeneration and preventing it becoming harmful during the first years – which is at the heart of much of the skill of natural regeneration silviculture. The main tools available are manipulation of the overhead canopy to control light and provision of favourable ground conditions for rapid growth of emerging seedlings. Too much shade which will suppress weed growth will not affect beech seedlings greatly, will eliminate any birch, will favour sycamore over ash and generally render seedlings more susceptible to mildew and damping off. Too little shade will allow vigorous weed growth and expose seedlings to frost damage.

Outside the wood, regeneration coming up in fields will mostly be affected by grass competition which competes especially vigorously for moisture. Ash and sycamore are very susceptible to grass competition and will rarely survive; oak, on the other hand, can often be found as a coloniser of such ground and will succeed, along with thorn species and other shrubs, if the field is left uncut and ungrazed.

Fungi and insects

Mention has already been made of the threat of mildew and damping off, which Rackham (1980) suggests is the main cause of failure of oak regeneration on damp sites, but in fact seedlings are no less at risk from such problems, especially when in damp overcrowded conditions, than they would be in a nursery bed.

Losses from insect and other invertebrate damage include chafer and cutworm girdling of roots and the root collar zone, defoliation by slugs and the effects of larval feeding reported in Shaw's (1968, 1974) well-known work with oak. Beneath an oak canopy final instar feeding on seedlings by leaf roller and winter moths, as larvae fall from the canopy to pupate, can be as damaging as any late frost since it occurs in June after the first leaves have emerged but before the seedling has replenished reserves consumed in the germination process. It explains in part why regeneration of oak under its own canopy is less profuse than might be expected, a point Lanier (1981) notes as now proved and accepted in France.

Assessing and Supplementing Regeneration

Natural regeneration is often patchy and not uniform. This appearance is not necessarily cause for concern. A gap in a carpet of regeneration may have only a few seedlings and look very poor, perhaps with less than one per square metre, but conventional planting is at a density of one seedling per 3–9 m^2 (1.7–3.0 m spacing) and provided this density of seedlings becomes established a satisfactory stand should result. The relative density is unimportant, it is the desirability of having about one seedling per square metre all over at the end of the first year which is important.

Figure 5.3 Oak and beech seedlings in September of first year; just the right time to assess regeneration (leaves still on) and to protect one of them with a treeshelter if at risk from browsing. (*A10896*)

Assessment of regeneration is best made in September while foliage is still visible showing where living seedlings are but after weed growth has largely ceased (Figure 5.3). Walking up and down the site, perhaps at 4 metre intervals, will take about an hour per hectare and reveal where regeneration has failed and may need supplementing. A sketch map of the gaps or marking with a stick will allow ready relocation when planting in the autumn or following spring.

Supplementary planting provides a chance to modify the balance of species to increase the proportion of desirable ones but will always be worth doing if there are gaps in the regeneration larger than 50 m^2 (7 × 7 m) without any seedlings of useful species. This is fifty times less dense than the stocking suggested above (1 seedling per m^2) but several plants will be put in and their chance of survival will normally be high. Except for ash and sycamore, waiting for another mast year to restock a gap is a waste under British conditions and either wildings, dug up from nearby dense patches of regeneration, or transplants (say, 3 or 4) should be planted at the centre of a gap of 7 × 7 m. Supplementing regeneration by direct sowing is rarely worthwhile. The seed is exposed to the same risks as that of the natural regeneration and large quantities are usually required to establish adequate numbers of plants.

Methods of Protection

Fencing

An area of natural regeneration does not differ from a newly planted stand in its requirement for protection from rabbits, deer and other mammals. The desirability of protection from mice, voles and birds in the first few months cannot be afforded by fencing. In general the decision to use fencing should be based on the same grounds as a plantation.

Treeshelters

Treeshelters have become one of the most useful means of protecting regeneration from both small and large mammals and birds on sites of less than about one hectare, in gaps and for group regeneration. Very important features are that they also clearly identify where the seedling is growing, will usually enhance its growth and permit easy use of herbicide to control weeds. Table 5.1 illustrates the protective benefit and the improved growth rate (Figure 5.4). Treeshelters allow opportunistic use of regeneration – recruiting it to fill gaps in plantations, stocking a neglected corner, taking advantage of advance growth, etc. (Figure 5.5). Treeshelters are likely to be the main method for harnessing the potential of natural regeneration in Britain on small sites and to have widespread application.

Treeshelters should be placed over young trees in September of their first year, see Figure 5.3, or in later years if still surviving but at risk. The aim is to protect one tree every 3 m, or at least 1000 per hectare, but ideally with no more than 5 m between any two treeshelters. Unless browsing pressure is extreme, additional stocking of trees will still arise raising overall density to acceptable levels for satisfactory development of broadleaved stands (Evans, 1984).

Table 5.1 Height development of matched pairs of oak plants/shoots showing the effects of individual protection by treeshelter. Number of pairs compared for each plant type in brackets.

Plant type	Mean height (cm)			
	Initial	Year 1	Year 2	Year 3
Natural regeneration (15)				
Treeshelter	14	27	54	76
No treeshelter	14	16	21	34*
Transplants (1+1s) (15)				
Treeshelter	32	52	94	123
No treeshelter	32	32	31	43*
Oak coppice shoots (10)				
Treeshelter	32	132	178	200
No treeshelter	29	32	44	43*

*Trees heavily browsed by red deer. In fact even better growth would have been achieved in this instance by using 1.8 m treeshelters.

Figure 5.4 The benefit of protecting seedling of oak natural regeneration (about 50 cm tall in treeshelter on left) compared with unprotected (right). (*A10899*)

Figure 5.5 Treeshelters used 'opportunistically' to protect young oak regeneration.

Weed Control

Manipulation of any overhead canopy to control weeds has been mentioned previously. Specific weed control among regeneration is best carried out either by hand or by very carefully placed herbicide applied with a weed-wiper, in the first year when seedlings are tiny. Efforts should be concentrated where stocking is light; dense patches will maintain themselves, at least until the next weeding. Where regeneration is very sparse or absent time should not be spent searching for the odd tree.

Where treeshelters are used, i.e. have been placed over seedlings in the autumn of the first year, conventional spot herbicide treatment can be used in second and subsequent years.

In general, uniform application of weeding is not needed; selective and careful treatment should be carried out.

Cleaning and Respacing

The cleaning requirements of natural regeneration do not differ from those of plantations; unwanted woody growth, including coppice and climbers such as *Clematis*, must not be allowed to threaten the desired crop. However, often the operation is combined with respacing where dense regeneration is thinned to prevent it becoming drawn up (Figures 5.6 and 5.7). In France rack cutting for ease of access and regular cleaning are recognised as essential early maintenance operations to secure a stand, see Lanier's (1981) and Everard's (1986) accounts.

Cleaning and respacing should begin once regeneration is about 2 m tall when bramble vigour is declining and some side branch suppression underway. Delay, especially for ash and sycamore, can be very injurious and ruin an otherwise promising crop. It is not adequate, as Schadelin (1937) stresses, simply to let individuals compete for superiority, i.e. a very early self-thinning, since this selects only for vigour and not stem form, which is so important for broadleaves. Where regeneration is thick respacing should be done lightly, for example reducing stocking from 50 000 trees ha^{-1} to 10 000 trees ha^{-1}, i.e. to 1 m spacing, on the first occasion and to more normal levels of 2500 to 3500 trees ha^{-1}, i.e. to about 1.5–2.0 m spacing, 2 or 3 years later, when trees have reached about 3 m average height. Frequent light cleanings/respacings are much

Figure 5.6 Respacing of young 2–3 m tall ash and beech natural regeneration. Unwanted growth cut by hand. (*A10891*)

Figure 5.7 Second respacing/cleaning of sycamore regeneration 4–5 m tall. (*A10898*)

safer than one heavy one. Investment in such cleaning and respacing is essential and rewarding and, along with much more careful weeding, is the compensating expense, for the considerable savings of no initial planting costs, incurred by properly managed natural regeneration.

Such work is costly over a whole hectare and compromises such as Garfitt's (1980) spaced cleaning are well worth adopting. He recommends cleaning and releasing two stems, which are far enough apart (>2 m) for each to be able to develop into pole size, approximately every 7–8 m through the stand. Each favoured tree is cleared to a distance of 1.2 m radius all round. The intervening matrix is untouched. The system ensures an even distribution of favoured trees whose crowns are given adequate room to grow and it is cheap to operate.

Practical Application

1. Apply the same degree of protection and good weed control to natural regeneration as would be required for a plantation.
2. Take time to assess stocking in the early autumn of the first year after regeneration has begun and infill gaps larger than 7 × 7 m by planting a small number of trees. Except for ash and sycamore, do not wait for further seed years to supplement stocking.
3. Treeshelters are an excellent tool to make the most of regeneration and to use it as opportunity arises. Place treeshelters over young trees in September, while leaves are still on to indicate that they are healthy.
4. Frequent, light cleaning and respacing are most important operations to secure high quality and health in a stand arising from natural regeneration; the work should not be skimped.

Chapter 6
Advance Regeneration, Recruiting Coppice Regrowth, and Suckers

Figure 6.1 Advance regeneration of sycamore (5-years-old) coming up prematurely beneath pole-stage ash and larch.

Advance Regeneration

This term refers to natural regeneration which appears in advance of felling operations. Indeed, it can arise from mid-rotation onwards once a crop begins to bear seed and thinning opens up a stand. It is of no silvicultural value in itself at this stage (Figure 6.1), other than indicating the potential for natural regeneration later on, and is unlikely to survive for very long. On occasion such regeneration of sycamore, beech or hornbeam can be used to advantage under oak to help keep stems clean of epicormics.

Sometimes advance regeneration will occur in profusion, without it being specifically sought, in the years immediately preceding normal rotation length and opportunity can be taken to use it to regenerate the site. When this is done one is 'following' the regeneration, a practice frequently advocated as the safest in the uncertain conditions in Britain. Aldhous (1981) recommends witholding any fellings until advance regeneration has become established, an approach well-suited to regenerating small areas as with the group system.

Advance regeneration is often patchy and uneven-aged and commonly occurs in stands of sycamore, ash and wild cherry (Figure 6.1). With these species it will not thrive long if the overstorey continues to cast heavy shade, but with beech advance regeneration can last many years growing slowly. If heavy shade is too prolonged, however, such beech regeneration tends to become bent topped; a condition which ruins its potential since it fails to recover properly even if given full light. Other disadvantages of 'old' advance regeneration is that it is often badly damaged during extraction and of poor form.

It is prudent to use advance regeneration when it occurs profusely around the time of final felling, say within 5 years of the planned date, and amending plans accordingly. There seems little point in husbanding it for any longer period except possibly for conservation and landscaping reasons when it might be used to help spread out the regeneration phase.

Recruiting Coppice Regrowth

A feature of all restocking of broadleaved woodlands is the prodigious growth of coppice from the cut stumps. Although coppice itself is a type of natural regeneration it has been considered elsewhere in detail (Crowther and Evans, 1986), including pure coppicing, coppice with standards, pollarding and related systems, and is not covered here.

When restocking woodland sites to achieve high forest, coppice growth is generally considered a weed competing with the seedling crop but it is possible to use the regrowth to stock bare patches and, on occasion, even for it to form the basis of the next stand. For all broadleaved species it is possible to thin vigorous coppice to one or two stems per stool (stump), in one or two operations over the first 15 or 20 years, and bring such a crop to all intents and purposes to a high forest condition (Figure 6.2). This practice is called storing coppice and has been quite widely applied in oak coppice, e.g. Pearson (1948).

Regeneration using coppice growth and then storing to high forest appears attractive but has several drawbacks. Development of such coppice growth, though initially vigorous, often falls off later in the rotation (Groos, 1953). Coppice shoots tend to have a weak attachment to the stump, and can break away, and almost always develop swept or curved butts. In addition, dark staining in ash, shake in oak, and other wood quality defects are believed to be more prevalent in stems of stored coppice than those of maiden origin.

Generally, storing coppice should not be the principal method of regeneration for stands grown for timber, but it should been borne in mind as an option. And, of course, the widespread neglect of coppicing this century has resulted in many stands of 'stored' coppice by default. Thinning of these to further the development of high forest is quite practicable, as seen for example in the extensive oak woods of Exmoor and Dartmoor – see description in Penistan (1986).

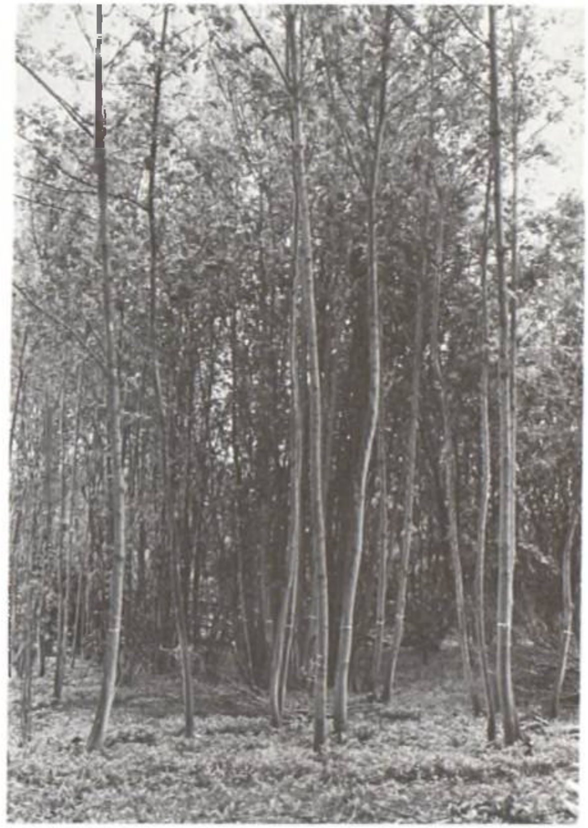

Figure 6.2 Sycamore coppice, 18-years-old, just thinned to one or two stems per stool to convert (store) to high forest. (Coppice in background still to be treated in this way, stems to be favoured are marked.)

Sucker Growth

A few species such as wild cherry, grey alder, false acacia, elm and wild service tree throw suckers, but though they can occasionally be used for stocking a gap adjacent to a parent tree they are otherwise of little silvicultural value owing to the species involved, and can sometimes even be a nuisance. One exception could be wild cherry where suckers and natural regeneration often come up together and could be used to advantage. Garfitt (1983) has proposed planting very widely spaced mother trees of cherry, growing them for 15 years, and then developing a fully stocked stand from all the additional sucker growth that would arise.

Chapter 7
Notes on Natural Regeneration by Species

Alders

Common alder is a light demanding pioneer which naturally regenerates easily to form small pure stands on areas of freshly exposed soil in wet localities (Figure 7.1). It is frequently a component of mixtures of ash, hazel and birches, and on heavier soils with oak where it can be a useful nurse. Common alder coppices well.

Ash

Throughout Britain ash shows a remarkable capacity to regenerate naturally both within and outside woodland. However, such regeneration will not necessarily make a worthwhile crop and should be viewed critically for three reasons. Firstly, occurrence of young regeneration, even if profuse, is no indication that the ground is a good ash site. Often on ill-suited sites, e.g. dry shallow soils over chalk, such regeneration will disappear after a few years. Secondly, as with all informal natural regeneration, no control has been exercised over the genetic quality of the parent trees. Many poorly formed trees are profuse seed bearers. Thirdly, uniform regeneration is difficult to achieve, dense patches interspersed by unstocked gaps are typical. Survival of high stocking levels results from locally favourable site conditions – moist but not poorly drained soil – rather than high initial density of germinating seeds.

Despite the above reservations, naturally occurring trees are often a valuable addition in mixed woodland. Also in mixed woodland ash regeneration in small openings is a useful way of restocking, especially if it continues to grow well beyond the fifth year (Figure 7.2). If ash regeneration is sought, and it should always be practicable to achieve on good ash sites (Helliwell, 1981), only a 25 per cent scattering of female trees is necessary. Typically a tree will bear about 10 kg of seed and will drop seed over many months, indeed any time

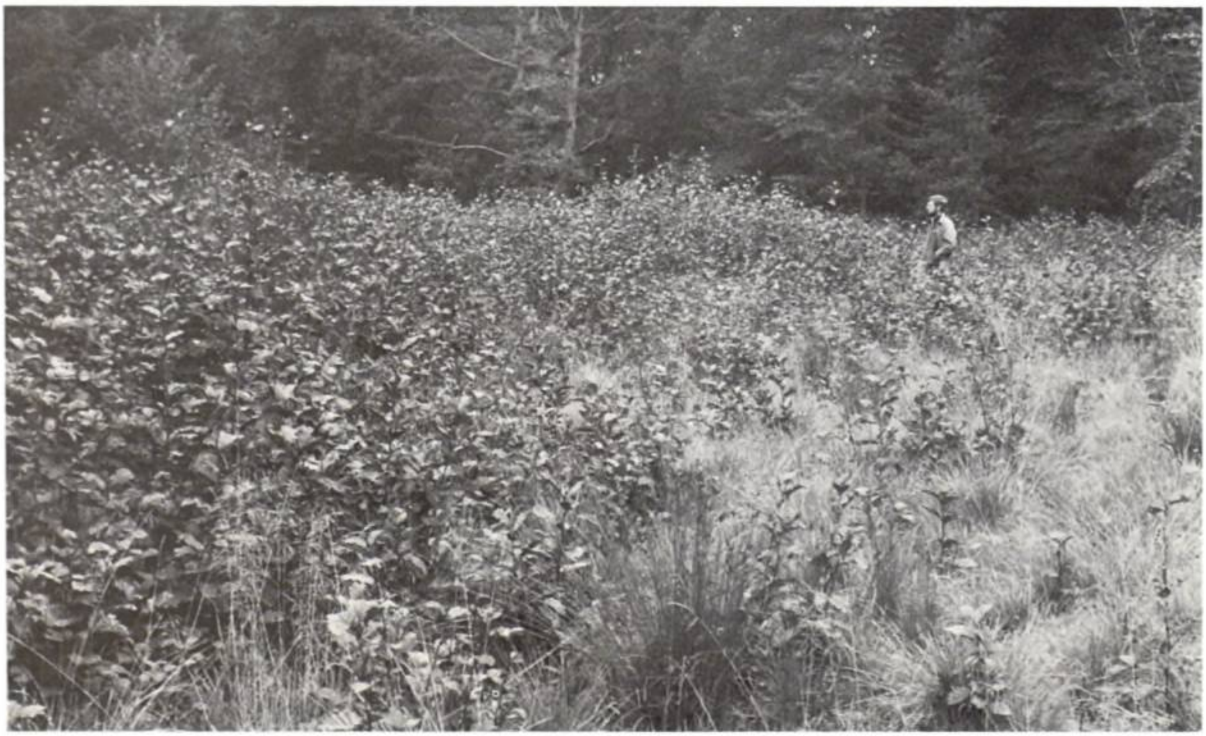

Figure 7.1 Dense natural regeneration of common alder on wet ground in Forest of Dean. (*A10619*)

Figure 7.2 Ash regeneration in small opening in a beech wood on chalk downland. It needs cleaning and respacing. (*A10890*)

from September to the following August (Gardner, 1977). It should be remembered that seedlings often do not come up until the second spring and they germinate 2–3 weeks earlier than the late flushing habit of older ash.

Initially, ash seedlings are moderately shade tolerant but within 3 or 4 years require increasing access to full overhead light for satisfactory growth, though Wardle (1957) suggests that the presence of partially suppressed seedlings in a wood presages successful regeneration. Most natural regeneration will need respacing and cleaning two or three times during the thicket stage though, unlike beech, it is generally able to grow through *Clematis* competition and brambles.

In general, in Britain, the most widespread use of ash regeneration will probably be to develop groups that do occur rather than pursuing silvicultural systems specifically trying to encourage it.

Beech

Although good mast years of beech are probably more infrequent than for any other broadleaved species in Britain, usually at intervals of 10 or more years, success with natural regeneration has not been especially difficult. Good examples can be found on the Chilterns, Cotswolds and South Downs. Beech regeneration is widespread in many western oakwoods and Watt (1931) reports self-sown beech as very common in Scotland. Although suited to the uniform shelterwood system, and there are a few examples in Britain, group regeneration is probably the most suitable silvicultural system for the smaller scale of forestry – felling coupes, woodland size, tradition – typical of the English lowlands compared with continental Europe.

Beech seed germinates in May with the emergence of the large unmistakable jade-green cotyledons. For many years seedlings are tolerant of deep shade. However, conditions beneath beech stands do not always favour regeneration, deep accumulations of litter being especially inimical which is often why regeneration is poor in acid beech woods (Cooper, 1986). Equally, more than the lightest scattering of ground vegetation is harmful, though Workman (1986) contends that no vegetation at all indicates too dense an overstorey for satisfactory regeneration.

Because mast years are few, opportunities for regeneration must not be missed and steps taken to ensure success when a good seed crop develops. Woodmice and pigeons consume great quantities of seed, seedlings in the cotyledon stage continue to be at risk from pecking by birds and from spring frosts, while rabbits and deer will browse seedlings and young growth heavily. Retention of overhead cover, which beech can tolerate for many years, will reduce frost risk and lessen vigour of weed growth. Beech is not a colonising species and, indeed, in openings in beech woodland it often only appears after initial colonisation by oak, ash, cherry, field maple, birch, etc., has developed.

In general, the safest practice is to pursue group regeneration, and do so by waiting for regeneration first to appear and then to begin felling to open the overstorey (Penistan, 1974; Aldhous, 1981).

Birches

Both birches produce seed freely, frequently and from an early age. Although seed viability is not always high the large quantities produced, and the fact that the seed is light and winged, enable colonisation by the species of almost any suitable site in Britain. Birches are light-demanding pioneer species and form a component of most British woodlands almost wholly as a result of natural regeneration.

Birches become readily established wherever there is bare mineral soil of moderate phosphate status. Dense ground vegetation can inhibit regeneration but birch will spring up on many grassy sites and amongst bracken and heather. Open, disturbed sites are where birch regenerates most profusely.

Natural regeneration of birch is not so much a silvicultural aim but a fact of life frequently adding to amenity along upland rides and on lowland heaths, providing woody growth to aid development of broadleaved stands or dappled shade to shelter regeneration of other species (Evans, 1984) and frequently as a weed in other crops (page 16).

A full account of birch regeneration is given by Harding (1981).

Field Maple

Field maple sets viable seed in most years though pure natural regeneration is rare. Seed often germinates in the second year after falling. In general, best development occurs on heavy soils which are calcareous at depth but without free lime at the surface. It is a common, minor component of mixed regeneration.

Gean (Wild Cherry)

Most wild cherry in older woodlands has arisen from unplanned natural regeneration or suckers which occur commonly in woodlands over chalk and limestone formations. The species sets viable seed at a young age and the seed is widely dispersed by birds though most still remains within 50 m of parent trees (Pryor, 1985).

Suckering is a feature of cherry and occurs up to 10 m from the parent stem and often comes up in mixture with seedling regeneration – see page 37. Initially, regeneration is shade tolerant but soon becomes strongly light-demanding and any overstorey should be removed after 3 or 4 years. On suitable sites natural regeneration of wild cherry is a useful addition to any stand.

Hornbeam

Hornbeam is principally a coppice species suitable for heavy clays but natural regeneration does occur singly or in small groups, mainly in south-east England. In northern France the species is a common component among natural regeneration of beech and oak and, though welcomed as an understorey during the life of a stand, it is removed before regeneration is started and normally cut back in early cleanings.

Limes

Small-leaved lime, the more widespread of the two native species, flowers profusely in most years but only sets viable seeds in warm summers. Generally, regeneration, which is uncommon and mostly localised, comes in mixed woodland with ash, hawthorn, field maple, birch, oaks and wild cherry, but occasionally small pure stands can be found.

Seed can survive for 2 years in the soil before germinating. Emerging seedlings bear deeply lobed cotyledons, unlike virtually all other species where they are always of simple outline even when later leaves are much divided.

Norway Maple

Norway maple flowers and sets seed regularly and is likely to be of potential for regeneration on calcareous soils where the species is one of the few which will grow well. In some situations it can be almost too prolific.

Oaks

Much of what has been written has already referred to oak. Natural regeneration is much commoner than often supposed, e.g. under even the most unpromising neglected oak coppice in the West Country, and can occur in most parts of Britain, though sessile oak sets seed less frequently than pedunculate. There is no general failure of oak seed to set, disperse or germinate.

Figure 7.3 Carpet of sycamore seedlings at the edge of a mixed pine and beech woodland on a base-rich downland site

To survive it needs protection and adequate light. Reference has been made elsewhere to seedling defoliation by caterpillars and the common sight of oak saplings growing up in thorn thickets.

Acorns can continue to germinate for 2 or 3 years after falling. The seedlings that develop have remarkable root:shoot ratios, typically between 4 and 6 in the first year, where the underground tissue acts as a storage organ leading to great resistance to browsing (Shaw, 1974) and explaining the good growth which occurs after stumping back and, perhaps, in the second year when grown inside treeshelters. After years of browsing a seedling can suddenly 'come away' and establish itself when pressure is relieved. The root:shoot ratio is much wider than other species including conifers which, in the first year, are typically closer to 2.

Oak is a strong pioneer species, expanding woodland fringes, and is an early arrival in scrub and colonisation of open ground. It can grow up through brambles, in less dense bracken and in grass.

Accounts of oak regeneration will be found in Newbold and Goldsmith (1981), Jones (1959) and Morris and Perring (1974) as well as in specific references already cited.

Turkey oak and its hybrids with our native species are common components of regeneration in southern Britain.

Rowan

Rowan or mountain ash fruits regularly, with seed widely dispersed by birds. Natural regeneration is common and widespread throughout Britain and growth of seedlings is initially very vigorous. The species is a very hardy light-demanding pioneer adding to amenity wherever it occurs; it is of little silvicultural importance.

Southern Beeches

Both *Nothofagus obliqua* and *N. procera* set viable seed and regenerate naturally despite being recent introductions.

Sweet Chestnut

Sweet chestnut is mostly thought of as a coppice species but timber trees are valuable when the wood is free from shake. The species fruits in most years and after warm summers the nuts develop well in southern England. It occurs naturally on lighter soils of south and east England and is fully 'naturalised' as a species to the point that Rackham (1980) regards it as a 'honorary native'.

Figure 7.4 Fifteen-year-old sycamore natural regeneration after first thinning; note vigorous coppice from stumps of the thinned out trees.

Sycamore

Sycamore is widely naturalised and regenerates more freely, on almost any soil which is deep enough (Jones, 1945), than any other broadleaved species apart from birches and willows, though a requirement for adequate soil phosphate may be critical (Helliwell, 1965). Indeed, there is concern (Peterken, 1981) that its ability to regenerate can become invasive, swamping ash, oak and beech (Figure 7.3). There are examples where sycamore has spread in a wood, e.g. Bedford Purlieus, but generally the natural regeneration of this robust species should be welcomed by foresters, other than on sites of special ecological interest or where grey squirrels are likely to be beyond control. Taylor (1982) suggests the case against sycamore as damagingly invasive on important sites is overrated.

Sycamore regeneration is often profuse on sites and in group openings where beech is hoped for (Stern, 1982) and it is generally more tolerant of shade than ash (see example in Figure 5.1) and can appear as advance regeneration under light crowned species such as ash (Figure 6.1). Rabbit browsing can be serious, perhaps more so than that of deer and sheep. With adequate light and moisture – considerable losses occur on dry thin soils – sycamore regeneration will develop as dense thickets which require cleaning and respacing two or three times to secure a stand and avoid drawn up straggly stems. Thinning should continue frequently and fairly heavily (Figure 7.4).

Willows and Sallow

Sallow and grey willow occur throughout Britain and come up freely on woodland sites and wetter patches of exposed mineral soil. Mostly they are a silvicultural nuisance needing control because of their vigorous growth and potential dominance of less competitive but more important crop species.

Whitebeams and Wild Service Tree

Whitebeam grows naturally in association with ash, beech, field maple and hawthorn; wild service tree may also be found with rowan, wild cherry and oaks. Both species are light-demanding pioneers though wild service tree can endure some shade. Whitebeam is an early coloniser in scrub on chalk but often survives the transition to woodland to form an occasional upper canopy tree.

Both species fruit strongly; wild service tree also readily produces suckers.

Glossary

Scientific names and authorities of English names used in text

ALDER	
Common	*Alnus glutinosa* (L.) Gaertn.
Grey	*Alnus incana* (L.) Moench.
ASH	*Fraxinus excelsior* L.
ASPEN	*Populus tremula* L.
BEECH	
Common	*Fagus sylvatica* L.
BIRCH	
Downy	*Betula pubescens* Ehrh.
Silver	*Betula pendula* Roth.
FALSE ACACIA	*Robinia pseudoacacia* L.
GEAN (Wild cherry)	*Prunus avium* L.
HAWTHORN	*Crataegus monogyna* Jacq.
HAZEL	
Common	*Corylus avellana* L.
HORNBEAM	*Carpinus betulus* L.
LIME	
Large-leaved	*Tilia platyphyllos* Scop.
Small-leaved	*Tilia cordata* Mill.
MAPLE	
Field	*Acer campestre* L.
Norway	*Acer platanoides* L.
OAK	
Pedunculate	*Quercus robur* L.
Red	*Quercus rubra* du Roi
Sessile	*Quercus petraea* (Mattusckha)
Turkey	*Quercus cerris* L.
ROWAN	*Sorbus aucuparia* L.
SOUTHERN BEECH	
Roble	*Nothofagus obliqua* (Mirb.) Bl.
Raoul	*Nothofagus procera* (Poepp. & Endl.) Oerst.
SWEET CHESTNUT	*Castanea sativa* Mill.
SYCAMORE	*Acer pseudoplatanus* L.
WHITEBEAM	*Sorbus aria* (L.) Crantz
Swedish	*Sorbus intermedia* (Ehrh.) Pers.
WILD SERVICE TREE	*Sorbus torminalis* (L.) Crantz
WILLOW	
Grey	*Salix cinerea* L.
Sallow	*Salix caprea* L.
White	*Salix alba* L.

References

ALDHOUS, J.R. (1972). *Nursery practice.* Forestry Commission Bulletin 43. HMSO, London.

ALDHOUS, J.R. (1981). Beech in Wessex – a perspective on present health and silviculture. *Forestry* **54**, 197–210.

ALLABY, M. (1983). *The changing uplands.* Countryside Commission report, CCP 153. Countryside Commission, Cheltenham.

BOULGER, G.S. (1907). The life-history of the Beech. *Quarterly Journal of Forestry* **1**, 230–279.

BOURNE, R. (1942). A note on beech regeneration in southern England. *Quarterly Journal of Forestry* **36**, 42-49.

BOURNE, R. (1945). Neglect of natural regeneration. *Forestry* **19**, 33–40.

BROWN, J.M.B. (1960). Ecological aspects of regeneration in British beechwoods. *Bulletin de l'Institut Agronomique et des Stations de Recherches de Gembloux, Hors Serie,* Vol. 1, 75-92.

COOPER, A. (1986). The composition and structure of deciduous woodland in County Down, N. Ireland. *Forest Ecology and Management* **14**, 219–234.

COTTERELL, R. (1950). Note about Symposium on ash as a forest tree in the British Isles. *Journal of Ecology* **38**, 409–412.

CROCKFORD, K.J., CORBYN, I.N. and SAVILL, P.S. (1987), *Management of woodlands for fuel and timber.* Oxford Forestry Institute. Report for the Energy Technology Support Unit of the United Kingdom Atomic Energy Authority (ETSU B1156).

CROWTHER, R.E. and EVANS, J. (1986). *Coppice.* Forestry Commission Leaflet 83 (second edition). HMSO, London.

EVANS, J. (1982). Silviculture of oak and beech in northern France: observations and current trends. *Quarterly Journal of Forestry* **76**, 75-82.

EVANS, J. (1984). *Silviculture of broadleaved woodland.* Forestry Commission Bulletin 62. HMSO, London.

EVELYN, J. (1665). *Silva: or a discourse of forest-trees and the propagation of timber in his majesty's dominions.* The Royal Society, London.

EVERARD, J. (1986). Oak and beech regeneration. *Forestry and British Timber* (Nov. 1986), 48–49.

FLOWER, N. (1980). The management history and structure of unenclosed woods in the New Forest, Hampshire. *Journal of Biogeography* **7**, 311–328.

FORESTRY COMMISSION (1982). *Forestry Commission census of woodlands and trees, 1979–82.* Forestry Commission, Edinburgh.

GARDNER, G. (1977). The reproductive capacity of *Fraxinus excelsior* on the Derbyshire limestone. *Journal of Ecology* **65**, 107–118.

GARFITT, J.E. (1963). Treatment of natural regeneration. *Forestry* **36**, 109–112.

GARFITT, J.E. (1980). Treatment of natural regeneration and young broadleaved crops. *Quarterly Journal of Forestry* **74**, 236–239.

GARFITT, J.E. (1983) . . . and no money. *Quarterly Journal of Forestry* **77**, 118–119.

GOODIER, R. and BALL, M.E. (1974). The management of upland broadleaved woodlands for nature and landscape conservation. In, *The management of broadleaved woodlands.* Supplement to *Forestry,* Oxford University Press 1974, 59–71.

GORDON, A.G. and ROWE, D.C.F. (1982). *Seed manual for ornamental trees and shrubs.* Forestry Commission Bulletin 59. HMSO, London.

GROOS, R. (1953). Oak stands from coppice allowed to grow on as high forest – a study of increment and yield. *Allgemeine Forst und Jadzeitung* **124**, 189–208.

HARDING, J.S. (1981). Regeneration of birch (*Betula pendula* Ehrh. and *Betula pubescens* Roth.). Addendum in Newbold and Smith (1981) – see below.

HARLEY, R.M. (1982). Problems in the silviculture of oak in Britain. In, *Broadleaves in Britain: future management and research,* eds. Malcolm, D.C., Evans, J. and Edwards, P.N., 19–23. Institute of Chartered Foresters, Edinburgh.

HELLIWELL, D.R. (1965). Factors influencing the growth of seedlings of sycamore and Norway spruce. *Quarterly Journal of Forestry* **59**, 327–337.

HELLIWELL, D.R. (1981). Silviculture of ash (*Fraxinus excelsior* L.) in Wessex. *Quarterly Journal of Forestry* **75**, 103–108.

JONES, E.W. (1945). Biological flora of the British Isles – *Acer* L. *Journal of Ecology* **32**, 215–252.

JONES, E.W. (1959). Biological flora of the British Isles – *Quercus* L. *Journal of Ecology* **47**, 169–222.

JOSLIN, A. (1982). Management of broadleaves in the Forest of Dean with special reference to regeneration. In, *Broadleaves in Britain: future management and research*, eds. Malcolm, D.C., Evans, J. and Edwards, P.N., 53–60. Institute of Chartered Foresters, Edinburgh.

JOYCE, P.M. and GARDINER, J.J. (1986). The management of oak in Germany: a silvicultural note. *Irish Forestry* **43**, 55–65.

KIRBY, K. (1982). The broadleaved woodlands of the Duddon Valley (Cumbria). *Quarterly Journal of Forestry* **76**, 83–91.

KOOP, H. and HILGEN, P. (1987). Forest dynamics and regeneration mosaic shifts in unexploited beech (*Fagus sylvatica*) stands at Fontainbleau (France). *Forest Ecology and Management* **20**, 135–150.

LAIDLAW, R. (1960). *Guide to British hardwoods*. Leonard Hill (Books) Ltd.

LANIER, L. (1981). Les degagements et nettoiements en futaie feuillue (Weeding and cleaning of broadleaved high forest). *Revue Forestier Française* **33**, 19–40 (special issue – Sylvicultures en futaies feuilles).

LOCKE, G.M.L. (1962). Changes in forest area through deforestation and natural colonisation of bare land by woody species. *The Chartered Surveyor* (May 1962), 3–6.

McNEIL, W.M. (1945). Preliminary observations on the influence of site conditions on natural regeneration, with special reference to Dunecht Estate, Aberdeenshire. *Forestry* **19**, 40–55.

MATTHEWS, J.D. (1963). Factors affecting the production of seed of forest trees. *Forestry Abstracts* **24**, i-xiii.

MATTHEWS, J.D. (1986). The history and status of uneven-aged forestry in Europe and Britain. *Proceedings of the discussion group on uneven-aged silviculture*, Pershore, 29 Oct. 1986, 3–16 (obtainable from D.R. Helliwell, Yokecliffe House, West End, Wirksworth, Derbyshire DE4 4EG).

MIEGROET, M. van, VERGEGGHE, J.F. and LUST, N. (1981). Trends of development in the early stages of mixed natural regenerations of ash and sycamore. *Silva Gandavensis* **48**, 1–29.

MILES, J. (1973). Early mortality and survival of self-sown seedlings in Glenfeshie. *Journal of Ecology* **61**, 63–98.

MORRIS, M.G. and PERRING, F.H. (eds) (1974). *The British oak: its history and natural history*. Published for the Botanical Society of the British Isles by E.W. Classey, Faringdon, Berks. B.S.B.I. Conference Reports No. 14 (376 pp.).

NEWBOLD, A.J. and GOLDSMITH, F.B. (1981). *The regeneration of oak and beech*. Discussion papers in Conservation 33, University College, London.

OTTO, H-J. (1987). Silviculture of broadleaved species in Western Germany. *Irish Forestry* **44**(2), 89–104.

PEARSON, W. (1948). Treatment of oak coppice areas. *Journal of the Forestry Commission* 19, 54–55.

PENISTAN, M.J. (1960). Forestry in the Belgian uplands. *Forestry* **33**, 1–7.

PENISTAN, M.J. (1974). The silviculture of beech woodland. In, *The management of broadleaved woodlands*. Supplement to *Forestry*, Oxford University Press 1974, 71–78.

PENISTAN, M.J. (1986). Oak in Wessex: an account of field studies 1982–84. *Forestry* **59**, 243–257.

PETERKEN, G.F. (1981). *Woodland conservation and management*. Chapman and Hall, London.

PONTEY, W. (1808). *The forest pruner*. J. Harding, London.

PROCTOR, M.C.F., SPOONER, G.M. and SPOONER, M.F. (1980). Changes in Wistman's Wood, Dartmoor: photographic and other evidence. Report of the *Transactions of the Devon Association for the Advancement of Science* **112**, 43–79.

PRYOR, S.N. (1985). The silviculture of wild cherry or gean. *Quarterly Journal of Forestry* **79**, 95–109.

PRYOR, S.N. and SAVILL, P.S. (1986). *Silvicultural systems for broadleaved woodland in Britain*. Oxford Forestry Institute Occasional Paper 32.

RACKHAM, O. (1980). *Ancient woodlands*. Edward Arnold, London.

SCHADELIN, W. (1937). *L'éclaircie. Traitment des forêts par la sélection qualitive*. Neuchâtel (éd. Attinger), 110 pp.

SCHROTTER, H. (1978). Fine hardwood species in silviculture and forest management. *Beitrage f.d. Forstwirtschaft* **3**, 114–122.

SHAW, M.W. (1968). Factors affecting the natural regeneration of sessile oak (*Quercus petraea*) in North Wales: 1. A preliminary study of acorn production, viability and losses. *Journal of Ecology* **56**, 565–583; 2. Acorn losses and germination under field conditions. *Journal of Ecology* **56**, 647–660.

SHAW, M.W. (1974). The reproductive characteristics of oak. In, *The British oak: its history and natural history*, eds. Morris, M.G. and Perring, F.H., 160–181. Published for the Botanical Society of the British Isles by E.W. Classey.

SHAW, M.W. (1982). The role of natural regeneration in maintaining broadleaved woodlands in Britain. In, *Broadleaves in Britain: future management and research*, eds. Malcolm, D.C., Evans, J. and Edwards, P.N., 248. Institute of Chartered Foresters, Edinburgh.

SMALL, D. (1982). Reproduction of even-aged high forest oak with special reference to New Forest statutory enclosures. In, *Broadleaves in Britain: future management and research*, eds. Malcolm, D.C., Evans, J. and Edwards, P.N., 65–71. Institute of Chartered Foresters, Edinburgh.

SMITH, M. (1983). The vanishing Welsh wildwoods. *Wildlife* (June 1983), 208–212.

SOMERVILLE, W. (1891). The natural regeneration of woods. *Transactions of the Royal Scottish Arboricultural Society* **13**, 63–82.

STERN, R.C. (1982). The use of sycamore in British forestry. In, *Broadleaves in Britain: future management and research*, eds. Malcolm, D.C., Evans, J. and Edwards, P.N., 83–87. Institute of Chartered Foresters, Edinburgh.

TAYLOR, N.W. (1982). *The ecology and status of sycamore, and its value for wildlife*. M.Sc. thesis, University College, London (unpublished).

TOWLER, R.W. (1980). What future for upland amenity woodlands? *Quarterly Journal of Forestry* **74**, 7–19.

TROUP, R.S. (1928). *Silvicultural systems*. The Clarendon Press, Oxford.

TUBBS, C.R. (1986). *A natural history of the New Forest*. Collins, London.

URQUHART, B.P. (1948). Regeneration of sycamore. *Quarterly Journal of Forestry* **37**, 89–91.

VENABLES, G.L. (1988). Marketing your timber. In, *Farming and forestry*, ed. G.R. Hatfield, 155–159. Forestry Commission Occasional Paper 17. Forestry Commission, Edinburgh.

WARDLE, P. (1957). Notes on the ecology of ash. *Forestry Commission Report on Forest Research* 1957, 107–108.

WATT, A.S. (1931). Preliminary observations on Scottish beechwoods. Introduction and Part 1. *Journal of Ecology* **19**, 137–157.

WORKMAN, J. (1986). Experience in the management of beech woodland. *Proceedings of the discussion group on uneven-aged silivculture*, Pershore, 29 Oct. 1986, 17–20 (obtainable from D.R. Helliwell, Yokecliffe House, West End, Wirksworth, Derbyshire DE4 4EG).

WRIGHT, T.W. (1982). The National Trust's approach to the regeneration of broadleaved woodland. In, *Broadleaves in Britain: future management and research*, eds. Malcolm, D.C., Evans, J. and Edwards, P.N., 77–81. Institute of Chartered Foresters, Edinburgh.

Printed in the United Kingdom for Her Majesty's Stationery Office
Dd 290505 C35 8/88 3936 12521

HMSO
BOOKS

HMSO publications are available from:

HMSO Publications Centre
(Mail and telephone orders only)
PO Box 276, London, SW8 5DT
Telephone orders 01-622 3316
General enquiries 01-211 5656
(queuing system in operation for both numbers)

HMSO Bookshops
49 High Holborn, London, WC1V 6HB   01-211 5656 (Counter service only)
258 Broad Street, Birmingham, B1 2HE   021-643 3740
Southey House, 33 Wine Street, Bristol, BS1 2BQ   (0272) 264306
9-21 Princess Street, Manchester, M60 8AS   061-834 7201
80 Chichester Street, Belfast, BT1 4JY   (0232) 238451
71 Lothian Road, Edinburgh, EH3 9AZ   031-228 4181

HMSO's Accredited Agents
(see Yellow Pages)

and through good booksellers

£3 net

ISBN 0 11 710263 6