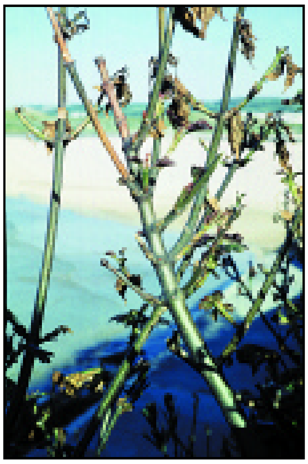
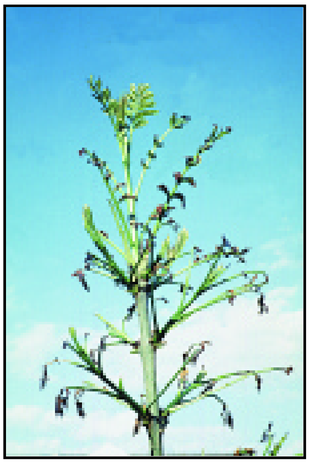
# *Sycamore and Ash*

# *A Review of Aspects Relevant to Irish Forestry*


COFORD

Pierre Binggeli and Brian S. Rushton

School of Applied Biological and Chemical Sciences,
University of Ulster, Coleraine, BT52 1SA, Northern Ireland

March 1999

# TABLE OF CONTENTS

# SUMMARY

This review considers the potential of both sycamore and ash for forestry in Ireland. Any information, from Great Britain, Ireland and Continental Europe, deemed relevant and reliable is summarized, including the nature of the planting material, provenance testing, silvicultural practices and other factors affecting growth and tree quality.

# 1 INTRODUCTION

## 1.1 OBJECTIVES

The major objective of this review is to collate and integrate the extensive body of information on sycamore (*Acer pseudoplatanus* L.) and ash (*Fraxinus excelsior* L.) available from a wide variety of relevant fields of study (biology, ecology, silviculture, provenance studies, breeding programmes, etc.) and geographical/cultural 'provenances' as possible in order to inform forestry practice. Information not essential to tree improvement and timber quality, such as site and climatic requirements, are not covered as they are beyond the scope of this review.

## 1.2 ASH AND SYCAMORE IN GREAT BRITAIN AND IRELAND: BACKGROUND

In Great Britain and Ireland, following decades of widespread conifer afforestation, the planting of broadleaves has markedly increased in the 1990s. When tree planting grants are sought, it is current forestry policy in both the Republic of Ireland and the UK to require the planting of a minimum area with broadleaves. In the Republic of Ireland the pace of planting has increased dramatically over the past decade. The afforestation programme under the 1996 'Strategic Plan for the Development of the Forestry Sector in Ireland' recommends planting 25,000 ha per annum until the year 2000 and 20,000 thereafter to the year 2035. This should result in the doubling of the forest estate. It is suggested that the private sector, and farmers in particular, would plant about 2/3rds of the total, and broadleaves would account for 20% of afforestation (Anon. 1996). However, in the north-west of Ireland afforestation by farmers has recently slowed down (R. Gallagher, pers. comm., 1997). Broadleaves have also been considered in alternative land use systems such as agroforestry and agrenforestry (Newman *et al.* 1989) where a tree crop is grown in conjunction with either livestock grazing or a mixture of agricultural, energy and forestry crops. The latter system, for example where sycamore is interplanted with coppiced *Alnus incana* (L.) Moench, is designed to provide shelter for sheep and cattle.

In Britain, as the quantity of broadleaves planted increased, it was realised that the quality of the broadleaved planting stock had to be improved. Over 25 million trees, mainly oak, ash, sycamore and cherry, are planted annually in Britain using uncertified seeds and unsuitable provenances (Cahalan *et al.* 1995). As a result the Ministry of Agriculture Food and Fisheries (MAFF) initiated a number of research projects including two in conjunction with the Forestry Authority on the 'Genetic improvement of broadleaves for farm forestry' (Cahalan 1993; Cahalan *et al.* 1995) and one with Horticulture Research International (Hammatt 1995). Between 1990 and 1994, Cahalan *et al.* (1995) investigated the selection, breeding, vegetative propagation and genetics of (mainly) ash and sycamore. The main thrust of the work was the evaluation of stands in England and Wales and identification of potential seed stands or exceptional individuals. Techniques for the vegetative propagation of individuals with exceptional phenotypes were also investigated. Provenance test trials of clonal material and seedlings from a variety of seed sources (including continental ones) have been established. Investigations on the phenotypic and genotypic variation of ash and sycamore were carried out, including the relationship between stem quality and the sex expression of ash and isoenzyme variation in sycamore.

The Horticulture Research International project was initiated in 1989 to apply horticultural expertise to improve the materials and methods available for establishing farm woodlands (Hammatt 1995). Although most of the work relates to *Prunus avium* (L.) L., micropropagation rejuvenation techniques for ash have also been developed (Hammatt 1994, 1996). Some of the work currently carried out includes the genetic improvement of ash and sycamore (Hammatt 1995).

In the UK, sycamore is one of the main species being assessed in an EU-funded Silvopastoral National Network Experiment (Sibbald 1990).

Although this recent research work was the first such scientific investigation in Britain, much empirical work was carried out by Lord Bolton and George Stevenson in Yorkshire particularly in relation to sycamore. However, the research work undertaken in the British Isles has been relatively limited compared to decades of investigations carried out in Central Europe and in Germany in particular. Little of this work has been taken into account in the development of recent research initiatives in Great Britain and Ireland probably as a result of the language barrier. However, it is more difficult to understand why much of the extensive ecological work on ash and sycamore in the British Isles or from elsewhere, but published in English, has received limited attention from foresters. Furthermore, there appears to have been little coordination of research effort between the three farm woodlands/agroforestry initiatives on ash and sycamore in Britain, particularly as two of the projects are being funded by the same government agency (i.e. MAFF).

In both the north and south of Ireland research work on broadleaves has been limited and outputs negligible. However, over the past ten years provenance trials of native oak and ash have been established and genetic improvement work, particularly of oak, has been initiated (Pfeifer 1991) and TEAGASC has been working on the vegetative propagation potential of ash and sycamore. The ECLAIR (European Collaborative Linkage of Agriculture and Industry through Research) project initiated in 1991 has identified and propagated about 100 clones of both ash and sycamore. This material was grafted to provide a germplasm bank for future use (D.G. Thompson, pers. comm., 1996).

Until very recently, foresters in Ireland, have generally relied upon the research carried out in Great Britain. This is to be somewhat expected as human and financial resources are rather limited. In the Republic, forestry has been much influenced by work in Britain whereas influences from Continental Europe have been small.

As a thorough review of the literature pertaining to sycamore and ash is beyond the scope of this paper, key publications dealing with various biological, ecological and forestry aspects of these two species are given in Table 1 and bibliographies on a number of relevant topics are enclosed as an appendix.

*Table 1: Key references relating to various aspects of the biology of ash and sycamore.*

| | ASH | SYCAMORE |
|---|---|---|
| **GENERAL REVIEWS** | Anon. (1995a)<br>Duflot (1995) | Binggeli (1992)<br>Hoffmann (1960) |
| **FORESTRY** | | |
| General | Duflot (1995)<br>Faure *et al.* (1975)<br>Franc & Ruchaud (1996)<br>Zeitlinger (1990) | Franc & Ruchaud (1996)<br>Kjölby *et al*. (1958)<br>Paul (1979)<br>Spellman (1981) |
| Plantations | Hulden (1941) | |
| Silviculture | Kerr (1995)<br>Thill (1970) | Pryor & Savill (1986)<br>Savill (1991) |
| Dendrology | | In *et al.* (1972) |
| Breeding | Larsen (1945) | |
| Seed procurement & nursery practice | Suska *et al.* (1994) | Suska *et al.* (1994) |
| **ECOLOGY** | | |
| Reviews | Falinski & Pawlaczyk (1995)<br>Wardle (1961) | Jones (1944) |
| Reproduction and regeneration | Lamb & Boshier (1994)<br>Tapper (1992) | Binggeli (1992) |
| Variation | | Galoux & Falkenhagen (1965) |
| Diseases | Butin (1995)<br>Grzywacz (1995)<br>Lanier *et al.* (1976) | Butin (1995)<br>Lanier *et al.* (1976) |
| Insect pests | Szmidt (1995) | |

*Note: full details of the above publications may be found in section 6 - references.*

# 2 SYCAMORE (*Acer pseudoplatanus* L.)

## 2.1 INTRODUCTION

Sycamore is a typical feature of the landscape of Great Britain and Ireland. The species is commonly found in urban, agricultural and wooded landscapes. Being an introduced species, which tends to spread into semi-natural vegetation, sycamore has been the focus of much controversy (see Binggeli 1993, 1994; Morton Boyd 1992a, 1992b, 1993a, 1993b; Taylor 1985 for details).

### 2.1.1 Great Britain

In Great Britain sycamore represents 8.8% of all broadleaved high forest (Evans 1987). According to Forestry Commission surveys, sycamore was the fourth commonest species in terms of volume and increased from 2.11 to 2.47 million $m^3$ from 1951 to 1980 (Allison & Peterken 1985). Yet Stern (1982) stated that sycamore has been under-used in modern forestry.

Sycamore has been widely planted as an amenity tree. In 1981 12% of trees planted by English and Welsh County Councils were sycamore whereas other agencies refrained from planting the species, although five years previously the opposite was true (Wright 1983). Sycamore has also been widely used for land reclamation, particularly of colliery spoil heaps (e.g. Jobling 1987).

### 2.1.2 Ireland

Sycamore (Crann bán in Irish, Webb 1977) was first recorded in Ireland in 1632 (Fitzpatrick 1933), but ring-counts suggest that a tree was planted around 1600 in Co. Donegal (Maxwell 1987). Plantings of sycamore made prior to the 18th century were in shelter belts, orchards and avenues on estates especially around Dublin and Cork; the planting of blocks began around 1700 (McCracken 1971). By the 18th century sufficient mature sycamore had been grown to be felled and sold. The fact that sycamore was added to the list of woods allowed in the making of barrels used in the export of meat, butter, tallow and fish in 1732 underlines its availability and economic importance (McCracken 1971). In more recent times sycamore timber has been of high value for turnery, furniture and flooring. It wears slowly and smoothly and has been sought after for the floors of dance halls (Fitzpatrick 1966). Currently sycamore wood is used in the production of the famous Lowden guitars in Newtownards, Co. Down (Doyle 1994).

In the north of Ireland the linen manufacturers required sycamore to make rollers. Up until the late 1950s the industry employed one or two men whose job was to find and buy hedgerow sycamore from farmers. As hedges were cut for fuelwood prior to a potato crop, on a five to ten year cycle, it is probable that the linen industry requirement for large sycamore may have created an incentive to farmers to retain and even promote sycamore stems in hedgerows. However, over the past four decades most sycamore timber has been exported to Germany. In the 1960s and 1970s the logs of trees felled throughout Northern Ireland were accumulated in Kesh and transported to Limerick to be processed and the veneer was then sent to Germany. Since the 1980s the logs have been exported directly to Germany (P.H. Blackstock, pers. comm., 1996).

It was estimated in 1985 that sycamore stands in State and private broadleaved woodland in the Republic of Ireland represented about 7% (3,447 ha) of the total (approximately 47,500 ha), but an earlier estimate (1970) suggested that pure sycamore woodlands accounted for only 79 ha (in 55 stands), the rest consisting of mixtures. Sycamore is the fifth commonest tree species in Ireland (Fitzsimons 1987; Keogh 1987). Sycamore regenerates naturally in 41% of Irish forestry plantations surveyed by Blackstock (1998). The regeneration tends to be predominantly found in older plantations mainly in the northeast at lower altitudes, but it is also common in the southwest at higher altitudes.

A survey of private woodlands in Northern Ireland by Graham (1981) showed that sycamore occupied 6% of the total area of woodlands greater than 0.5 ha and that most stands were planted before 1929, some between 1929 and 1954, but none since. By volume sycamore was the fifth most frequent species and represented 12% of the total. Within Northern Ireland large variations were observed between different areas. It was the second most important species (20%) in Co. Derry, was common in Tyrone, Antrim, Down and Armagh with about 10% but was absent from Fermanagh. Sycamore occurred mostly on leached soils and sometimes on gleyed soils and was the most productive broadleaf after beech. In Co. Antrim, Tomlinson *et al.* (1987) found that ash and sycamore were the commonest tree species and that most submature woodland trees were either ash or sycamore. They forecast a large change in species composition in future decades as individuals of these two species mature.

procurement strategy of FORESTART consists of gathering seeds from easily accessible trees with a good shape. It is thought that, subconsciously, trees with large fruits might be selected (A. Gordon, pers. comm., 1995). FORESTART attempts to collect seeds from different parts of Great Britain (e.g. southern England and coastal areas of Scotland) as it is thought they might be better adapted to local conditions as a result of selection.

In 1993, in the Republic of Ireland, 70% of the 1 million planted seedlings were imported, chiefly from the Netherlands, and the seed source used in the home production "was equally divided between Dutch and Irish provenances with a small proportion of English origin" (Anon. 1994a, p. 23). Coillte's recommended seed origins for sycamore are: Dutch, northern German, British and French registered sources (Anon. 1994b).

**BOLTON ESTATE**

Over the past six decades the planting material used at the Bolton Estate has varied greatly (Stevenson 1985). Prior to 1949 planting material was obtained from Scotland or Hilliers and many trees from Hilliers had purplish foliage. However, no other information is available on the characteristics of these provenances. Seeds from the Hilliers material on the Bolton Estate were later collected and sent to Aberdeen.

During the time when Mr George Stevenson was the estates forester (1949-1986) most planting material was derived from two trees growing on open ground in front of the Hall. These were known to date from 1720 (Worsley 1989). Most of the seed was collected from one of these trees, Old Red Stem. Old Red Stem was selected as a seed source because of its age, because of its freedom from basal bending, buttressing, and fluting and because it had light branching.

Despite much branch pruning for seed gathering and subsequent resprouting the tree is still strikingly different from most other sycamores growing around it. When Old Red Stem was selected as a seed source, it had a narrow crown and low branches below 6 m with no evidence of any branch pruning. Branches were typically close to the horizontal (still observable today), whereas recent branches of epicormic origin are fastigiate. Surrounding trees are typical of open grown sycamore found throughout the British Isles with very large lower branches arching upwards and nearly reaching as high as the leading stem.

In recent years all planted sycamore on the Bolton Estate have come from commercial nurseries.

### 2.2.2 Continent

In the Federal Republic of Germany, the German Forest Seed and Planting Stock Law (enacted 1979) and related legislation established two categories of propagative material: 'selected' and 'tested'. The legislation was subsequently extended to include sycamore (Muhs 1985).

In Continental Europe sycamore seeds are collected from certified stands and from seed orchards. In Germany there are 14 sycamore seed orchards covering 27.6 ha (J. Kleinschmit, pers. comm., 1996). Although in Bavaria seeds are collected "from all trees which bear fruits" (W. Ruetz, pers. comm., 1996), qualitative observations of fruiting material from a seed orchard (Teisendorf in Bavaria) and collected material in Denmark indicate that foresters tend to select seeds from protandrous individuals. Although most protandrous individuals bear mostly parthenocarpic fruits, a certain proportion of individuals do produce large seed crops and bear more samara per infructescence than protogynous individuals (Binggeli 1990). Protogynous trees do, however, bear larger samaras with larger seeds. Unintentionally foresters appear to select trees with the greatest number of fruits per infructescence rather than focussing on fruit size. The implications of this selection are unclear and need to be investigated.

## 2.3 PROVENANCE TESTING

### 2.3.1 Great Britain

Although Gordon & Fraser (1982) stated that for sycamore "no evidence is available comparing seed source" Helliwell & Harrison (1978) grew seedlings of six European provenances in 24 different soils. After two years they found significant differences in growth of seedlings between soils, but not between provenances and no significant soil x provenance interaction was observed.

Recently Cundall *et al.* (1998) established sycamore provenance trials at five farm forestry sites using seeds from ten provenances including six from the UK. After one year significant differences in height growth and root-collar diameter were observed between provenances and between sites, although no site x provenance interaction was observed (Cahalan *et al.* 1995). By year 4, the investigated, three of which (GOT, LAP and PGI) showed much variability. Eighty one of the 83 upper altitude clones could be correctly identified using these three enzyme systems.

## 2.5 SILVICULTURE

### 2.5.1 Great Britain

The silviculture, growth, yield and economics of sycamore in Wessex has been documented by Stern (1989). Lorrain-Smith (1988) investigated the economic aspects of sycamore outlined in the Forestry Commission Management Guidelines and highlighted the lack of available data to carry out a proper assessment.

Pure sycamore coppice (about 2,500 ha or about 7% of the total coppiced area) occurs on a wide range of soils in the south of England, whereas coppice with standards is rare. The rotations are typically of 10 to 20 years (Evans 1984).

Due to its “prolific seeding” sycamore, as well as ash, is potentially good for selection and shelterwood management systems of high forest on appropriate soils (Pryor & Savill 1986). The shelterwood management of sycamore was first applied in England by Garfitt (1953, 1963) to hazel coppice, which was thinned out in groups to release ash and sycamore saplings which regenerated underneath it. However, in areas where the hazel coppice was subsequently not completely removed it has remained dominant (Pryor & Savill 1986). Although little use of the shelterwood system appears to have been made, Pryor & Savill (1986) suggest that together with ash, sycamore is the most promising species for shelterwoods. This is because no gap planting is necessary owing to its vigorous regeneration and, additionally, it requires less weeding than oak.

In areas where the selection system is practised, sycamore and ash are the most abundant seedlings and are used as nurse trees for the final crop species, usually beech, oak or cherry (Pryor & Savill 1986).

An alternative silvicultural system has been recently proposed by Duncan (1996) for both sycamore and ash and a number of other broadleaved species where the species are grown at wide spacings (between 275 and 2,500 stems/ha) combined with regular pruning. This appears to offer the production of quality timber in “relatively short rotations”.

**BOLTON ESTATE**

Lord Bolton (1949) remarked that “first quality sycamore is not easy to grow” and it is “not surprising that foresters have been discouraged”. However, he believed that under the right climatic, topographic and soil conditions as well as adequate silvicultural treatments sycamore should provide the most profitable final crop. He identified the disposal of thinnings (which are important for cash flow) and the production of stems greater than 20 inches quarter-girth (required to fetch high prices within about 70 years) as the main difficulties in growing sycamore.

Site requirements, according to Bolton, include high rainfall and rich soils (but not too heavy) including even shallow ones on fissured limestone. In England these conditions limit the optimal growth of sycamore to northern areas and to some southern sites.

The main essential features of the silvicultural treatment carried out at the Bolton Estate include the need to always plant in mixtures followed by frequent thinning and stem pruning (Stevenson 1985; Worsley 1989).

The standard species mixture for planting was European larch and sycamore. Formerly ash was included in the species mix but it did not grow well. Spacing between plants and planting design have changed over time. Initially planting consisted of one line of sycamore and four of larch with plants 1.5 m apart. This scheme resulted in larch inhibiting the development of the crowns of sycamore. More recently, group planting has been favoured with sycamore being planted in square groups of 16 and 2 m apart with one square of sycamore for three of larch. Thinning is usually carried out every four years. The last thinning and final spacing is obtained after 35 years. All sycamores are pruned first to 3.5 m and later to 5.5 m. After 70 years the trees reach crop size of 14 inches quarter-girth. Mixtures with Japanese larch have also been laid out at the Bolton Estate and elsewhere in Yorkshire. Whelan (1995) reported a 45 years old stand with three rows of sycamore alternating with three rows of larch. After 38 years two rows of larch were removed. The experience of such a late initial thinning indicated that a more effective thinning would be on a ten year cycle.

*Figure 2: Impact of flowering on sycamore branch architecture. The trees are 20 m apart in the Birch-Rowan-Hazel woodland at Murlough Bay, Co. Antrim, Northern Ireland. The tree on the left has yet to flower whereas the tree on the right has a flowering intensity of 74% (i.e. the percentage of buds producing an inflorescence over a period of six years, see Binggeli 1992 for details) which results in increased shoot bifurcation and much reduced shoot annual increment (Hugh Wright).*

### 2.6.2 Insect pests

In the British Isles aphids, and in particular *Drepanosiphum platanoidis*, build up very large populations on sycamore. Dixon (1971) suggested that in the absence of aphids tree growth could be increased up to 280%, although the very presence of aphids and the production of large quantities of honeydew, which falls on the ground, may increase nutrient cycling and thus the aphids might have a smaller impact on tree growth than at first thought. Some trees appear to have some resistance to aphids as there is much tree-to-tree variation in aphid population sizes (Wellings *et al.* 1985; Leather 1996).

### 2.6.3 Vertebrate pests

Damage caused by the bark-stripping grey squirrel, *Sciurus carolinensis*, is currently the greatest threat to sycamore timber production in most of Great Britain and Ireland. Damage is most severe between May and August when the sap flow is the greatest and is most serious at the pole-stage. In England high levels of damage were correlated with a thick phloem layer, high density of young squirrels and whether bark-stripping had occurred during the previous year (Kenward *et al.* 1996). These authors also found that self-seeded sycamores were less susceptible to damage, a phenomenon noticed in relation to rabbit damage in pre-myxomatosis days. Trees found in areas where pheasants were fed in both winter and spring suffered more damage. However, the two main factors associated with heavy damage were the presence of seed-bearing tree species within 200 m of plantations and sites with less than 50% ground cover. Control of grey squirrels in spring is effective using Warfarin in hoppers scattered throughout a wood whereas shooting and trapping has little impact on levels of damage or squirrel numbers. At the Bolton Estate coppiced sycamores, which grow much faster than uncoppiced individuals, attracted most of the squirrels and appeared to act as decoys (G. Stevenson, pers. comm., 1995). Coppicing a small proportion of the crop may reduce damage to other trees and deserves to be investigated. As grey squirrels appear to favour stems of intermediate sizes (10-25 cm in diameter in beech, Mountford (1997)) the coppicing cycle needs to be carefully planned. Kenward & Dutton (1996) provide management guidelines and planting strategies to limit costs and damage due to grey squirrels.

In recent years rabbits have become once again a serious problem in establishing broadleaves and the problem may yet get worse as resistance of the rabbit to myxomatosis increases and the virus becomes weaker. Since 1804 sycamore has often been regarded as somewhat resistant to rabbit attacks (e.g. Sheail 1971) but its susceptibility appears to vary. Bolton (1956) reported that in the south of England sycamore was almost immune to rabbits. At around the same time in northern England, sycamore saplings, which originated from planted stock, were highly susceptible to rabbits whereas naturally regenerated saplings were not susceptible except during very severe winters. All larger trees were liable to damage until the bark started producing scales. Lord Bolton who reported these observations could only conclude that he could

# 3 ASH (***Fraxinus excelsior*** L.)

## 3.1 INTRODUCTION

Ash is common throughout Europe including Great Britain and Ireland. The species rarely forms pure stands and is usually uncommon in most forest types, but in recent decades it has been observed that ash sapling populations have been increasing in regions where it had hitherto been uncommon. In Germany this process has been described as 'Vereshung' ('ashification') and is thought to result from ash saplings having the ability to root faster and deeper than beech. This rooting difference is of particular importance during dry summers which have been common in recent years (Rysavy 1991; Rysavy & Roloff 1994). On the other hand much ash dieback, more particularly in hedgerow trees, has been observed in Britain in recent years (Hull & Gibbs 1991). It has been suggested that mechanical damage to the roots results in increased insect pests attacks and ultimately these insects are the cause of dieback (Foggo & Speight 1993; Foggo *et al*. 1994).

For reviews of the reproductive biology and the site and climatic requirements of ash readers are referred to Lamb & Boshier (1994) and Joyce *et al.* (1998), respectively.

## 3.2 PLANTING STOCK

### 3.2.1 Great Britain and Ireland

**PAST PLANTING**

Little concrete evidence is available to ascertain the type of planting material formerly used. It is probable in Great Britain that planting relied on local provenances. In Ireland it is likely that planting on large estates used material imported from Great Britain whereas farmers would have probably used local seed sources or natural regeneration.

**20TH CENTURY PLANTING**

Like other broadleaves, ash has traditionally been imported from continental nurseries or seedlings have been grown from continental seed sources (Gordon & Fraser 1982). Of the 2 million ash seedlings planted in the Republic of Ireland in 1993 only 35% were produced locally, the remaining being imported mainly from the Netherlands (Anon. 1994a, p. 23).

FORESTART has difficulties supplying the British market with material from native seed sources because in most years good seed production is very localised. Thus FORESTART has to import from the continent to meet demand (A. Gordon, pers. comm., 1995). In Continental Europe special efforts are made to store seeds in order to supply seeds of the right provenances every year. This does not appear to have been an issue in British and Irish forestry. In Ireland Coillte's recommended seed origins are from registered Irish, Dutch and British sources (Anon. 1994b).

As part of the British Hardwoods Improvement Programme seed orchards have been established between 1993 and 1998 in England (Savill 1998).

### 3.2.2 Continent

In Germany nine seed orchards have been established covering a total area of 21.8 ha. One of these, in Baden-Württemberg, established in the early 1990s, is 2.2 ha in extent and contains 32 and 35 of male and female clones respectively (Anon. 1995b). Ideally the seed orchard should have a 1:2, male:female ratio, but due to the fact that in silviculture female trees are selected against (poorer shape and growth than male individuals) it is impossible to find enough female trees in registered stands (A. Franke, pers. comm., 1995).

In France the genus *Fraxinus* is represented by two species, *F. excelsior* and *F. oxyphylla* Bieb. ex Willd. (a slow growing species with inferior timber), and these two species coexist in some regions. They can hybridize and this causes problems in the setting up of *F. excelsior* seed orchards. Jeandroz *et al.* (1995), using nuclear ribosomal DNA, have been able to discriminate between the two species. They also found that some trees identified as *F. excelsior* on the basis of their morphological characteristics were misclassified. Using their technique *F. oxyphylla* or hybrids can be removed from breeding populations and seed orchards.

## 3.3 PROVENANCE TESTING

### 3.3.1 Great Britain

Under nursery conditions, Cahalan *et al.* (1995) found significant differences in height and stem diameter between eight continental provenances. After one year, height varied between 9 and 21 cm and French provenances proved to be the tallest. Early results for a trial of British provenances found no significant differences in either height or diameter but as the results were very variable

## 3.5 SILVICULTURE

### 3.5.1 Great Britain and Ireland

Pryor & Savill (1986) considered the potential of ash for selection and shelterwood management systems of high forest as good on suitable soil types. As ash regenerates vigorously in gaps, it does not need to be planted and it was perceived as a promising species for shelterwoods. Ash seedlings were abundant where the selection system was practised and the species was used as a nurse for the final crop (beech, oak or cherry).

Hart (1995) reported an interesting management programme for ash on a shelterwood system in Northamptonshire where heavy and selective thinning had been applied. The wood consisted of a mixture of 30-50 years old coppiced ash, oak, lime and sycamore with some oak and ash standards.

In Ireland two silvicultural trials have recently been established. In 1994 ash with beech, Sitka spruce and Norway spruce were planted on uncultivated grassland at Summerhill, Co. Meath. The main objective of the project was to develop guidelines for the successful establishment of trees on enclosed farmland (Ward 1994) including the examination of the effect of various herbicide treatments on tree growth. Harmer (1996) has investigated the impact of *Deschampsia flexuosa* (L.) P. Beauv. and *Poa trivialis* L. on seedling root systems. He found that grass reduced the production of new roots and a greater proportion of the dry matter was allocated to smaller roots (< 2 mm in diameter) thus emphasising the importance of weed control.

TEAGASC has a young 2 ha broadleaf plantation including ash. The effects of spacing and weed control are being investigated. The study also includes the impact of pruning on tree quality (Bulfin & Radford 1995).

Mostly in the late 1980s Coillte established a number of trials to look at the effects of NPK + lime application and spacing (some specifically for hurley ash), and a trial on cutaway bog (Pfeifer 1991). Culleton *et al.* (1996) reported that on lowland fertile sites there is no need to add fertilizer during the establishment phase as tree increment growth was not affected by various fertilizer applications.

A study of a limited number of low-yielding ash stands (yield classes 4 and 6) over a wide geographical area studied by Kilbride (1997) indicated that there was a correlation between growth and percentage of sand in the substrate.

Fitzsimons & Luddy (1986) have investigated various aspects of the production of ash timber for hurleys. They examined a number of silvicultural systems, including mixtures with Christmas trees (noble fir), tree guards and fertilizer, on three soil types and assessed the economics of these various systems in comparison with a Sitka spruce crop grown on the same sites.

Kerr (1995), in his review of the silviculture of ash in southern England, has stressed the importance of weed control during establishment and the importance of frequent crown thinnings. In Ireland, Culleton *et al*. (1995) found that after three years there was no difference in total height between saplings when herbicide was applied to the whole plot or in strips (0.5 and 1 m wide) coupled with mown grass strips. However, when the grass strips were not mowed, saplings were significantly taller - this might be the result of the protection from wind that the grass provides in the early stages of growth.

As indicated above (Section 2.5.1) Duncan (1996) has suggested planting ash at wide spacings to encourage the production of quality timber in “relatively short rotations”.

### 3.5.2 Continent

Much of the management of ash in forestry on the continent relies on natural regeneration followed by frequent pruning and thinning in some regions. Duflot (1995) and Hubert & Courraud (1994, pp. 224-227) stressed the importance of regular pruning in the early years. Of great significance is the early summer pruning which even includes the removal of some leaves on the terminal shoot (Duflot 1995). In France ash, in pure and dense stands, is not favoured as it often suffers from a high incidence of canker disease. Whenever cankers are observed the affected trees are removed prior to pruning (Hubert & Courraud 1994, p. 225). In older stands the poor growth of trees is usually the result of thinning carried out too late (Thill 1970). The timing and intensity of the thinning regime is critical for the production of quality timber, i.e. wood with similar sized annual growth rings (Duflot 1995). Fast growth rates are thought to reduce the incidence of black heart as trees can be harvested at an earlier age (Hubert & Courraud 1994, p. 225).

### 3.6.3 Ecotypic differentiation

In Germany, two ecotypes have been recognized by Münch & Dieterich (1925), who differentiated populations from dry limestone soil (Kalkesche) from those of fertile soils (Wasseresche) in terms of leaf hairiness. Observations by Helliwell (1982) and Kerr (1995) do not support the existence of such distinctions in England and in Germany and Weiser (1995) has now shown that the ecotypic hypothesis is unfounded. Two phenological forms (early and late flushing) and two subspecies are sometimes recognized (Boratynska 1995).

### 3.6.4 Stem forking

One of the main problems with the production of quality ash is the frequent forking. If trees fork before they reach the height of 6-9 m their commercial value is greatly reduced. Kerr (1995) recorded variation in branching habit and asserted that "forked ash trees can be classified into two groups; those which have persistent forking up the main stem and fastigiate branches (this form of forking is most likely to be genetic and trees should be removed in early thinnings), and those which have one single fork (most likely caused by frost, birds or, less commonly, the ash bud moth (*Prays fraxinella*))." In England, over one winter season, 25% of buds of naturally regenerated saplings were damaged by the ash bud moth, and of these 71% eventually died (Foggo 1996a). Bud loss in saplings not only affects stem form but also reduces height increment growth (Foggo 1996b). Foggo (1996a) has suggested that factors likely to decrease the moth's impact on ash in plantations include site conditions (plenty of light and adequate water supplies) and silviculture (regular thinning to reduce the possibility of moth population densities increasing as shade increases). As other ash species, such as *F. angustifolia*, or its hybrid with *F. excelsior*, are less susceptible to the moth damage they might be planted instead. The selection of resistant varieties is considered a possibility by Foggo, but no information on variation in susceptibility to moth herbivory within the species exists.

Blackstock & Binggeli (1997) found that after four growing seasons most ash saplings had forked and that trees exhibiting extensive forking were also those growing fastest. It was concluded that formative pruning is essential to produce a crop of desired height.

In France spring frosts are the main known cause of terminal bud abortion, which leads to forking. Thirteen years after planting only 30% of the trees had not forked (Ningre *et al.* 1992). (See also Section 3.6.2.)

Fungal growth and drought, and subsequent bud death also result in forking (Hull 1991; Ningre *et al*. 1992) and it has even been stated by Misson (1967) that whenever the tap root encounters major soil changes, it stops growing and the stems tend to bifurcate. Misson also claimed that "female flowers" occur terminally, thus causing forking of branches, whereas "male flowers" are borne laterally. Since inflorescences are not initiated on terminal buds, flowering does not cause stem forking. In areas where bullfinches (*Pyrrhula pyrrhula*) feed heavily on ash buds stem forking becomes a problem (Summers 1981).

### 3.6.5 Diseases

Over 300 species or varieties of fungi as well as numerous viruses, bacteria and mycoplasms cause diseases in ash and many result in wood defects (Grzywacz 1995). Black heart, or the darkening of the centre of the stem, is the most significant stem defect in ash. This condition is common in Great Britain and Ireland, as well as the continent, and markedly reduces the timber's market value. Opinions differ greatly as to the reasons for the occurrence of black heart. Evans (1984) stated that wet "swampy" ground, slow growing trees over 80 years old and stored ash of coppice origin are often associated with black heart, whereas Misson (1967) reported that coloured wood appears at an age of 60-70 years, on dry soil rather than damp soil. According to Duflot (1995) trees where trunks bifurcate, and in the process create a small depression where water can gather, are the most likely to exhibit wood coloration. Disagreements on the effect of black heart on the physical properties of the wood also exist (see Duflot 1995; Kerr 1995, 1998). Kerr (1998) has recently concluded that black heart does not result from fungal attack but is a chemical stain of unknown origin and that there are large regional and site differences in incidence.

### 3.6.6 Animal pests

A large number of arthropod species are found on ash. However none is solely associated with ash; all affect other tree species, both broadleaves and conifers (Szmidt 1995). A number of these invertebrates cause damage to various parts of the tree.

# 4 CONCLUSIONS

In providing this review it is hoped that forest researchers will have been made more aware of the number of interacting variables which affect both ash and sycamore and which ultimately affect the quality and the value of the crop. In order to improve the forestry potential of ash and sycamore we believe that it is essential that various aspects of forestry research and practice (e.g. silviculture, tree breeding, nursery practice) should be investigated in an integrated manner. This, however, can only be achieved by a coordinated effort which draws knowledge and skills from a number of fields, including forestry (i.e. provenance testing, tree selection and breeding, silviculture), ecology (particularly reproductive biology and herbivory) and morphology (particularly tree architecture). To our knowledge, such an approach has not been initiated for any European broadleaf species. For instance, in Irish forestry little or no emphasis has been placed on tree biology or tree pest and tree/disease interactions. None of these themes are covered in Pilcher & Mac an tSaoir (1995).

# 6 REFERENCES


Allison, H. & Peterken, G.F. (1985). Changes in the number of non-woodland trees in Britain since 1945. Arbor. J. 9, 259-269.

Anon. (1994a). Pathway to progress - a programme for forest research and development. COFORD, Dublin.

Anon. (1994b). Recommended seed origins for use in Irish forests. Making Headway with Forest Research. Coillte Res. Dev. Info. Note no. 13.

Anon. (1995a). Nasze Drzewa Lesne: Monografie Popularnonaukowe Tom 17. Jesion wyniosly - *Fraxinus excelsior* L. Instytut Dendrologii, Kórnik.

Anon. (1995b). Erntezulassungsregister für Samenplantagen als Ausgangsmaterial zur Gesinnung von Ausgewähltem Vermehrungsgut. In Internationale Exkursion zum Thema: "Forstliches Vermehrungsgut der Esche (*Fraxinus excelsior* L.) im Bereich der Forstdirektion Freiburg". Forstliche Versuchs- und Forschungsanstalt Baden-Württemberg, Freiburg.

Anon. (1996). Strategic plan for the development of the forestry sector in Ireland. Envir. Bull. 31, 21-22.

Binggeli, P. (1990). Detection of protandry and protogyny in sycamore (*Acer pseudoplatanus* L.) from infructescences. Watsonia 18, 17-20.

Binggeli, P. (1992). Patterns of invasion of sycamore (*Acer pseudoplatanus* L.) in relation to species and ecosystem attributes. D.Phil. Thesis, University of Ulster, Coleraine.

Binggeli, P. (1993). Conservation value of sycamore. Quart. J. For. 87, 143-146.

Binggeli, P. (1994). Controlling the invader. Tree News, Autumn, 14-15.

Binggeli, P. & Power, A.J. (1991). Gender variation in ash (*Fraxinus excelsior* L.). In Proceedings of the Irish Botanists' Meeting, p. 42. University College Dublin, Dublin.

Blackstock, P.H. (1996). Personal communication. 26 Tullynahinnion Rd, Portglenone, Co. Antrim, Northern Ireland, BT44 8EL.

Blackstock, P. H. (1998). Broad-leaved tree and shrub invasion of conifer plantations in Ireland. D.Phil. Thesis, University of Ulster, Coleraine.

Blackstock, P. & Binggeli, P. (1997). The need for shelter when growing ash and sycamore. Ir. Timber For., July/August, 32-33.

Bolton, Lord (1949). The growth and treatment of sycamore in England. Quart. J. For. 43, 161-167.

Bolton, Lord (1956). Profitable forestry. Faber & Faber, London.

Boratynska, K. (1995). Systematyka i geograficzne rozmieszczenie. In Anon. Jesion wyniosly - *Fraxinus excelsior* L., pp. 54-64. Instytut Dendrologii, Kórnik.

Bornand, G.-H. (1973). Les "feuillus divers", des essences à ne pas oublier! Forêt 26, 127-133.

Bucur, V. (1983). Vers une appréciation objective des propriétés des bois du violon. Rev. for. fr. 35, 130-137.

Bulfin, M. & Radford, T. (1995). COFORD broadleaf committee - Visit to Kinsealy Research Centre. TEAGASC, Kinsealy.

Buriánek, V. (1994). Vysledky proveniencního vyzkumu s javorem klenem. Zprávy Lesnického Vyzkumu 39(4), 1-4.

Butin, H.H. (1995). Tree diseases and disorders: causes, biology, and control in forest and amenity trees. Oxford University Press, Oxford.

Cahalan, C.M. (1993). Genetic improvement of broadleaves for farm forestry. In Lee, S. (Ed.) Progeny testing and breeding strategies, pp. 178-180. Forestry Authority, Roslin.

Cahalan, C.M., Plowman, M.R., Baker, C. & Cundall, N. (1995). Genetic improvement of broadleaves for farm forestry. Final Report, For. Comm. / MAFF Contract CSA 1449, Alice Holt.

Carlier, G., Peltier, J.P. & Gielly, L. (1992). Comportement hydrique du frêne (*Fraxinus excelsior* L.) dans une formation montagnarde mésoxérophile. Ann. Sci. For. 49, 207-223.

Clarke, E.M. (1992). Wind damage to sycamore (*Acer pseudoplatanus* L.) trees in stands on the coast of Donegal. M.Sc. Thesis, University of Ulster, Coleraine.

Condon, F.A. & Jarvis, P.J. (1989). Trees and shrubs in the hedgerows of Knock, Co. Mayo, western Ireland. Ir. Nat. J. 23, 12-16.

Franc, A. & Ruchaud, F. (1996). Autécologie des feuillus précieux: frêne commun, merisier, érable sycomore, érable plane. Etudes du CEMAGREF: Série Gestion des Territoires 18, 1-170. CEMAGREF, Riom.

Franke, A. (1995). Der internationale Eschen-Herkunftsversuch (*Fraxinus excelsior* L.) im Forstbezirk Kenzingen/Baden-Würtemberg. In Internationale Exkursion zum Thema: "Forstliches Vermehrungsgut der Esche (*Fraxinus excelsior* L.) im Bereich der Forstdirektion Freiburg", pp. 1-13. Forstliche Versuchs- und Forschungsanstalt Baden-Württemberg, Freiburg.

Franke, A. (1995). Personal communication. HVA Baden-Württemberg, Abt. Botanik & Standortskunde, Arbeitsbereich Forstpflanzenzüchtung, Wonnhaldester. 4, 79100 Freiburg, Germany.

Gallagher, L.U. (1987). The market for Irish hardwood timbers. Ir. For. 44, 135-145.

Gallagher, R. (1997). Personal communication. Western Forestry Co-op, Sligo, Co. Sligo, Ireland.

Galoux, A. & Falkenhagen, E. (1965). Recherches sur la variabilité génécologique de l'érable sycomore (*Acer pseudoplatanus* L.) en Belgique. Trav. Stn. Rech. Eaux For. (A) 10, 1-60.

Garfitt, J.E. (1953). The rehabilitation of devastated woodlands. Forestry 26, 28-32.

Garfitt, J.E. (1963). Treatment of natural regeneration. Forestry 36, 109-112.

Garfitt, J.E. (1989). Growing superior ash. Quart. J. For 83, 226-228.

Giertych, M. (1995). Genetyka. In Anon. Jesion wyniosly - *Fraxinus excelsior* L., pp. 355-370. Instytut Dendrologii, Kórnik.

Gibbs, J.N. (1997). Fifty years of sooty bark disease of sycamore. Quart. J. For. 91, 215-221.

Gill, R.M.A. (1992). A review of damage by mammals in north temperate forests: 1. Deer. Forestry 65, 145-169.

Gordon, A.G. (1995). Personal communication. FORESTART, Church Farm, Shrewsbury, SY4 4AQ, U.K.

Gordon, A.G. & Fraser, D.K. (1982). The supply and utilisation of seed of native broadleaves. In Malcolm, D.C., Evans, J. & Edwards, P.N. (Eds) Broadleaves in Britain. Future management and research, pp. 161-168. Institute of Chartered Foresters, Edinburgh.

Graham, T. (1980). Hedgerows and small woods in Northern Ireland. In Nature conservation and agriculture. University of Ulster, Coleraine.

Graham, T. (1981). Private woodland inventory of Northern Ireland 1975-1979. Department of Agriculture, Northern Ireland, Belfast.

Gregory, S.C. (1982). Bark necrosis in *Acer pseudoplatanus* L. in northern Britain. Eur. J. Forest Path. 12, 157-167.

Greig-Smith, P.W. & Wilson, M.F. (1985). Influence of seed size, nutrient composition and phenolic content on the preferences of bullfinches feeding on ash trees. Oikos 44, 47-54.

Groves, L. (1992). An investigation into the natural variation in the form of ash (*Fraxinus excelsior*). B.Sc. Thesis, Oxford Forestry Institute. Cited in Kerr (1995).

Grzywacz, A. (1995). Wazniejsze choroby infekcyjne. In Anon. Jesion wyniosly - *Fraxinus excelsior* L., pp. 371-415. Instytut Dendrologii, Kórnik.

Hammatt, N. (1994). Shoot initiation in the leaflet axils of compound leaves from micropropagated shoots of juvenile and mature common ash (*Fraxinus excelsior* L.). J. exp. Bot. 45, 871-875.

Hammatt, N. (1995). Progress in HRI's genetic and propagation research with broadleaved farm woodland trees. Agrofor. Forum 6(1), 40-45.

Hammatt, N. (1996). *Fraxinus excelsior* L. (Common ash). In Bajaj, Y.P.S. (Ed.) Biotechnology in agriculture and forestry, Vol. 35. Trees 4, pp. 172-193. Springer, Berlin.

Konnert, M. (1992). Isoenzymanalysen bei Bergahorn (*Acer pseudoplatanus* L.) - Klonidentifizierung. In Biochemische Untersuchunge zur Genetik von Waldbaumpopulationen, pp. 77-84. Schriftenreihe der Landesanstalt für Forstwirtschaft Nordrhein-Westfalen, Sonderband.

Lamb, A. & Boshier, D. (1994). The reproductive biology of common ash (*Fraxinus excelsior*): a literature review. Unpublished MS, University of Oxford, Oxford.

Lanier, L., Joly, P., Bandoux, P. & Bellemère, A. (1976). Mycologie et pathologie forestière. Tome 2. Pathologie forestière. Mason, Paris.

Larsen, C.S. (1945). Blornstring og Foraedling hos Ask (*Fraxinus excelsior* L.). [English translation.] Dansk Skovforen Tidsskr. 30, 49-89.

Leather, S.R. (1996). Colonisation and distribution of sycamore aphid on sycamore trees in south-east Britain. Bull. Brit. ecol. Soc. 27, 214-218.

Le Goff, N. & Ottorini, J.-M. (1996). Leaf development and stem growth of ash (*Fraxinus excelsior*) as affected by tree competitive status. J. appl. Ecol. 33, 793-802.

Lorrain-Smith, R. (1988). The economic effects of the 'Guidelines for the management of broadleaved woodland'. Timber Growers, Sipley.

Maxwell, R. (1987). The Bishop Bedell sycamore at The Palace of Kilmore, County Cavan. Moorea 6, 28.

McCracken, E. (1971). The Irish woods since Tudor times. David & Charles, Newton Abbot.

Misson, R. (1967). Considérations sur le frêne commun (*Fraxinus excelsior* Lin.). Bull. Soc. Roy. For. Belg. 74, 117-124.

Morton Boyd, J. (1992a). Sycamore - a review of its status in conservation in Great Britain. Biologist 39, 29-31.

Morton Boyd, J. (1992b). Sycamore - a review of its status in conservation in Great Britain. Scott. For. 46, 304-310.

Morton Boyd, J. (1993a). Sycamore and conservation. Tree News Summer, pp. 14-16.

Morton Boyd, J. (1993b). Sycamore - a review of its status in conservation in Great Britain. Arbor. J. 17, 425-435.

Mountford, E.P. (1997). A decade of grey squirrel bark-stripping damage to beech in Lady Park Wood, UK. Forestry 70, 17-29.

Muhs, H.J. (1985). Forstliches Saatgutrecht in seiner Bedeutung für Forstpflanzenzüchtung und Waldbau. In Forum - Genetik - Wald - Forstwirtschaft, pp. 28-36. University of Göttingen, Göttingen.

Münch, E. & Dieterich, V. (1925). Kalkesche und Wasseresche. Forstl. Wschr. Silva 13, 129-135.

Murray, R., Cooper, A. & McCann, T. (1991). A landscape ecological study of Fermanagh District. University of Ulster, Coleraine.

Newman, S.E., Lawson, G.J., Callaghan, T.V., Wainwright, J. & Scott, R. (1989). Biomass production from agrenforestry systems. In Grassi, G., Pirrwitz, D. & Zibetta, H. (Eds) Energy from biomass 4, 111-118. Elsevier, London.

Ningre, F., Cluzeau, C. & Le Goff, N. (1992). La fourchaison du frêne en plantation: causes, conséquences et contrôle. Rev. for. fr. 44 (suppl.), 104-114.

Oliver, J. (1996). 1995 - a punishing year for trees in north east Wiltshire. BSBI News 71, 16-17.

Ottorini, J.M., Le Goff, N. & Cluzeau, C. (1996). Relationships between crown dimensions and stem development in *Fraxinus excelsior*. Can. J. Forest Res. 26, 394-401.

Paul, D.K. (1979). Secretariat notes on *Acer*. In Technical consultation on fast growing plantation broadleaved trees for the Mediterranean and temperate zones, Vol. 1, pp. 121-140. FAO, Rome.

Pfeifer, A.R. (undated). Current research on broadleaves. Unpublished MS.

Pfeifer, A. (1991). Coillte broadleaf experimental programme. Coillte Res. Dev. Info. Note no. 3.

Thresh, J.M. (Ed.) Pests, pathogens and vegetation, pp. 385-391. Pitman, Boston.

Suska, B., Muller, C. & Bonnet-Masimbert, M. (1994). Graines des feuillus forestiers: de la récolte au semis. INRA, Champenoux.

Szmidt, A. (1995). Wazniejsze szkodniki. In Anon. Jesion wyniosly - *Fraxinus excelsior* L., pp. 417-442. Instytut Dendrologii, Kórnik.

Tapper, P.-G. (1992). On ash. Botaniska Institutionen, Stockholm.

Taylor, N.W. (1985). The sycamore (*Acer pseudoplatanus*) in Britain: Its natural history and value to wildlife. Ecology and Conservation Unit, University College, London.

Thill, A. (1970). Le frêne et sa culture. Les Presses Agronomiques de Gembloux, Gembloux.

Thill, A. (1975). Contribution à l'étude du frêne, de l'érable sycomore, et du merisier. Bull. Soc. r. for. Belg. 82, 1-12.

Thompson, D.G. (1996). Personal Communication. Coillte, Newtownmountkennedy, Co. Wicklow, Ireland.

Tomlinson, R.W., Butcher, M. & Kerr, S. (1987). Antrim AONB tree survey. Summary report. Queen's University, Belfast.

Ward, D. (1994). Forest establishment on enclosed farmland. Coillte, Bray.

Wardle, P. (1961). Biological Flora of the British Isles, *Fraxinus excelsior* L. J. Ecol. 49, 739-751.

Webb, D.A. (1977). An Irish Flora. Dundalgan Press, Dundalk.

Webb, R. (1985). Farming and the landscape. In Aalen, F.H.A. (Ed.) The future of the Irish landscape, pp. 80-92. Trinity College, Dublin.

Weiser, F. (1965). Untersuchungen generativer Nachkommenschaften von Esche (*Fraxinus excelsior* L.) trockener Kalkstandorte und grundwassern beeinflusster Standorte im Gefässversuch bei differenzierten Wasser- und Kalkgaben. Forstw. Cbl. 84, 44-64.

Weiser, F. (1971). Erste Ergebnisse einer Herkunftsversuches mit Bergahorn, *Acer pseudoplatanus* L. Beitr. Forstwirtsch. 5, 225-227.

Weiser, F. (1974). Ergebnisse 10 jähriger vergleichender Anbauversuche mit generativen Nachkommenschaften von Eschen (*Fraxinus excelsior* L.) trockener Kalkstandorte und grundwassernbeeinflusster Standorte. Beitr. Forstwirtsch. 1, 11-16.

Weiser, F. (1981). Zielstellung und Ergebnisse einer 15 jährigen Bestandesnachkommenschaftsprüfung bei Bergahorn, *Acer pseudoplatanus* L. Beitr. Forstwirtsch. 15, 142-144.

Weiser, F. (1995). Beitrag zur Existenz von Ökotypen bei Gemeiner Esche (*Fraxinus excelsior* L.). Forstarchiv 66, 251-257.

Weiser, F. (1996). Bestandesnachkommenschaftsprüfung von Bergahorn. Allg. Forst Z. 51, 774-777.

Wellings, P.W., Chambers, R.J., Dixon, A.F.G. & Aikman, D.P. (1985). Sycamore aphid numbers and population density. 1. Some patterns. J. Anim. Ecol. 54, 411-424.

Whelan, D.P. (1995). Lakes Forest District and north Yorks Moors Forest District - Friday 13th May 1994. Ir. For. 52, 106-109.

Williams, A., Mayhead, G.J. & Good, J.E.G. (1991). Vegetative propagation of sycamore (*Acer pseudoplatanus* L.). Quart. J. For. 85, 179-182.

Wittrock, V.B. (1886). Ueber die Geschlechtverteilung bei *Acer platanoides* L. und einigen anderen *Acer*-Arten. Bot. Cbl. 25, 55-68.

Worsley, M. (1989). Where sycamores are noble. Country Life, 26th Oct., 84-85.

Wright, S.E. (1983). Recent amenity tree and shrub planting in the rural landscape of England and Wales. J. environ. Mgmt 16, 17-34.

Zeitlinger, H.J. (1990). Die Esche. Österr. Forstz. 2, 31-34.

Cornu, D., Garbaye, J., Laplace, Y., Tacon, F. le & Picard, J.-F. (1977). Le bouturage de feuillus divers. Rev. for. fr. 29, 278-284.

Garbaye, J. & Tacon, F. le (1979). Production rapide de plants d'érable sycomore et de frêne sur tourbe fertilisée, comparaison des plants issus de graines où de boutures. Rev. for. fr. 31, 227-233.

Garbaye, J., Tacon, F. le & Riedacker, A. (1978). Fast production of strong hardwood plants on fertilized peat and under plastic tunnel. In Oswald, H. (Ed.) Symposium on establishment and treatment of high-quality hardwood forests in the temperate climatic zone, p. 343. Station de Sylviculture et de Production No. 78/08, Nancy-Champenoux.

Hanus, D. & Rohr, R. (1985). Micropropagation de l'érable par bouturage in vitro de fragments de germinations de trois espèces. Can. J. Bot. 63, 277-280.

Jinks, R. (1995). The effects of propagation environment on the rooting of leafy cuttings of ash (*Fraxinus excelsior* L.), sycamore (*Acer pseudoplatanus* L.) and sweet chestnut (*Castanea sativa* Mill.). New Forests 10, 183-195.

Kobert, H. (1979). Vegetative Vermehrung von Waldbäumen durch Triebstecklinge. Ber. eidg. Anst. forst. Versuchsw. 201, 1-8. Reprinted from Schw. Forster 115, 491-497, 516.

Kohnert, H. (1991). Neue Möglichkeiten bei der heterovegetativen Vermehrung von Waldbäumen durch die Chip-Veredlung. Holzzucht 45(3-4), 30-32.

Koster, R. (1977). Vegetative propagation of broadleaved tree species in Holland. In Vegetative propagation of forest trees - physiology and practice, pp. 149-159. Swedish University of Agricultural Sciences, Uppsala.

Kruger, H. (1982). Vegetative Vermehrung von Nadel- und Laubhölzern. Allg. Forstz. 93, 243-244, 246.

Rohr, R. & Hanus, D. (1987). Vegetative propagation of wavy grain sycamore maple. Can. J. For. Res. 17, 418-420.

Soudain, P. (1977). Le traitement frigorifique des boutures: aspects physiologiques - revue bibliographique. In Lemaire, F., Riedacker, A. & Gagnaire-Michard, J. (Eds) Multiplication végétative et rhizogenèse. Problèmes posés aux pépiniéristes, horticulteurs et forestiers. CNRS, Nancy-Champenoux.

Spethmann, W. (1982). Stecklingsvermehrung von Laubbaumarten - Einfluss von Erntetermin, Substrat und Wuchstoff. Deutsche Gartenbau (2), 42-48.

Spethmann, W. (1982). Stecklingsvermehrung von Laubbaumarten. 1. Versuche mit Ahorn, Esche, Eiche, Buche, Kirsche, Linde, Birke. Allg. Forst- Jagdztg 153, 13-24.

Tacon, F. le., Garbaye, J., Bouchard, D. & Churin, J.L. (1992). Les différentes techniques de production de plants et le contrôle de la mycorrhization chez les feuillus précieux. Rev. for. fr. 44 (suppl.), 47-54.

Verger, M. & Cornu, D. (1992). Premier bilan du programme de multiplication végétative de l'érable ondé. Rev. for. fr. 44 (suppl.), 156-159.

Williams, A., Mayhead, G.J. & Good, J.E.G. (1991). Vegetative propagation of sycamore (*Acer pseudoplatanus* L.). Quart. J. For. 85, 179-182.

Zakrzewski, J. & Adamczyk, J. (1991). Effect of apical supplying [of] IAA upon the induce rhizogenesis in isolated shoot segments of *Acer pseudoplatanus* L. Ann. Warsaw Agric. Univ. SGGW, For. Wood Techn. 42, 71-75.

### 7.2.3 Diseases

Abbott, R.J., Bevercombe, G.P. & Rayner, A.D.M. (1977). Sooty bark disease of sycamore and the grey squirrel. Trans. Br. mycol. Soc. 69, 507-508.

Alcock, S. & Wheeler, B.E.J. (1983). Variability of *Cryptostroma corticale*, the causal fungus of sooty bark disease of sycamore. Pl. Path. 32, 173-176.

Anon. (1952). Sooty bark disease of sycamore: *Cryptostroma corticale*. Leafl. For. Comm. 30, 1-7.

Leith, I.D. & Fowler, D. (1987). Urban distribution of *Rhytisma acerinum* (Pers.) Fries (tar spot) on sycamore. New Phytol. 108, 175-181.

Lonsdale, D. (1987). Prospects for long term protection against decay in trees. Bull. For. Comm. 65, 149-155.

Moreau, C. & Moreau, M. (1951). Nouvelles observations sur le dépérissement des érables. Bull. Soc. Linn. Normandie 9(7), 66-67.

Moreau, C. & Moreau, M. (1951). La "Suie" des sycomores à Paris. Bull. Soc. Mycol. Fr. 67, 404-418.

Müller, K. (1912). Zur Biologische der Schwarzfleckenkrankheit der Ahornbäume, hervorgerufen durch den Pilz *Rhytisma acerinum*. Zentbl Bakt. ParasitKde Abt II, Bd 36, 67-98.

Müller, K. (1912). Über das biologische Verhalten von *Rhytisma acerinum* auf verschiedenen Ahornarten. Ber. dt. bot. Ges. 30, 385-391.

Nageleisen, L.-M. (1994). Le dépérissement actuel de feuillus divers: hêtre, merisier, alisier torminal, érable sycomore, peuplier, châtaignier, charme, aulne glutineux. Rev. for. fr. 46, 554-562.

Nash-Wortham, J. (1966). Sooty bark on sycamore - a new occurrence on sawn timber. Quart. J. For. 60, 330.

Nash-Wortham, J. (1967). Occurrence of *Cryptostroma corticale* on sawn timber of sycamore (*Acer pseudoplatanus* L.). Trans. Br. mycol. Soc. 50, 327.

Nikusch, I.W. (1992). Die Platanennetzwanze, *Corythuca ciliata* Say, und die Rhododendronzikade, *Graphocephala coccinea* Forster, zwei neuere sich ausbreintende Problemschädlinge für das öffentliche Grün in Deutschland. Gesundte Pflanzen 44, 311-315.

Peace, T.R. (1955). Sooty bark disease of sycamore - a disease in eclipse. Quart. J. For. 49, 197-204.

Peace, T.R. (1962). The pathology of trees and shrubs. Clarendon Press, Oxford.

Pearce, R.B., Sümer, S., Doran, S.J., Carpenter, T.A. & Hall, L.D. (1994). Non-invasive imaging of fungal colonization and host response in the living sapwood of sycamore (*Acer pseudoplatanus* L.) using nuclear magnetic resonance. Physiol. Mol. Pl. Pathol. 45, 359-384.

Phillips, D.H. & Burdekin, D.A. (1992). Diseases of forest and ornamental trees. MacMillan, London.

Piearce, G.D. & Gibbs, J.N. (1981). *Verticillium* wilt of trees and shrubs. Arboric. Leafl. 9, 1-9.

Polák, Z. & Branisová, H. (1991). Viruses in some deciduous forest trees. Sborník UVTIZ, Ochrana Rostlin 27, 1-8.

Quaroni, S., Sardi, P. & Locci, R. (1980). Disseccamenti apicali in *Acer pseudoplatanus* associati a Diaporthe eres Nits (*Phomopsis acerina* Pir. & Car.). Riv. Patol. Veg. 16, 109-115.

Rawling, K.L. (1972). Death of sycamore trees at Otley, Yorks. Quart. J. For. 66, 201-207.

Rayner, A.D.M. (1993). The fundamental importance of fungi in woodlands. Brit. Wildl. 4, 205-215.

Rayner, A.D.M., Bevercombe, G.P., Brown, T.C. & Robinson, A. (1981). Fungal growth in a lattice: A tentative explanation for the shape of diamond-cankers in sycamore (*Acer pseudoplatanus*). New Phytol. 87, 383-393.

Riecken, I. (1985). Versuche zur Verhütung der Rotpustelkrankheit (*Nectria cinnabarina*). Z. PflKrankh. PflPath. PflSchutz 92, 516-529.

Riecken, I. (1986). Mit Spritzungen gegen Rotpustelkrankheit? Dt. Baumsch. 38, 417, 419.

Riecken, I. (1987). Rotpustelkrankheit - Versuche mit neuen Wundverschlussmitteln. Dt. Baumsch. 39, 420-423.

Risbeth, J. (1970). The role of Basidio spores in stump infection by *Armillaria mellea*. In Toussoun, T.A., Robert, V., Nelson, B. & Nelson, P.E. (Eds) Root diseases and soil-born pathogens, pp. 141-146. University of California Press, Berkeley.

Cussigh, F. (1989). Un nuovo *Curculio* L. dei monti Berici (Vincenza) (Coleoptera Curculionidae). Boll. Soc. Entomol. Ital. 121, 43-52.

Cussigh, F. (1991). Osservazioni su *Curculio vicetinus* Cussigh, un inquilino delle galle fogliari di *Pediaspis aceris* Gmelin modificate da *Dichatomus acerinus* Förster. Mem. Soc. ent. ital., Genova 70, 181-206.

D'Arcy-Burt, S. & Blackshaw, R.P. (1991). Bibionids (Diptera: Bibionidae) in agricultural land: review of damage, benefits, natural enemies and control. Ann. appl. Biol. 118, 695-708.

D'Arcy-Burt, S. & Chandler, P.J. (1987). Irish Bibionidae and Scatopsidae (Diptera: Nematocera). Ir. Nat. J. 22, 224-231.

Dixon, A.F.G. & Russel, R.J. (1972). The effectiveness of *Anthocoris nemorum* and *A. confusus* (Hemiptera: Anthocoridae) as predators of the sycamore aphid, *Drepanosiphum platanoides*. 2. Searching behaviour and the incidence of predation in the field. Entomologia exp. appl. 15, 35-50.

Emmet, A.M. (Ed.) (1979). A field guide to the smaller British Lepidoptera. British Entomological and Natural History Society, London.

Fernie, T.P. (1852). A new insect, a parasite of the sycamore. Naturalist (Morris) 111, 265.

Gäbler, H. (1955). Forstliche Samenschädlinge und ihre Bedeutung. Arch. Forstw. 4, 434-438.

Gäbler, H. (1958). Beiträge zur Kenntnis der Schadinsekten der Blüten und Samen von Forstgehölzen. Arch. Forstw. 7, 786-827.

Gange, A.C. (1996). Positive effects of endophyte infection on sycamore aphids. Oikos 75, 500-510.

Gillanders, A.T. (1900). Notes on Phytopti or gall mites and arboreal beetles. Sect. 1. Phytopti or gall mites. Trans. Manchester Microsc. Soc. 67-72.

Leather, S.R. (1996). Colonisation and distribution of sycamore aphid on sycamore trees in south-east Britain. Bull. Brit. ecol. Soc. 27, 214-218.

Lengerken, H. von (1930). Über die geographische Verbreitung und die Blattschnittmethode des Ahornblattrollers (*Deporaus tristis* F.). Zool. Anz. 90, 269-273.

Littledyke, M. & Cherrett, J.M. (1978). Defence mechanisms in young and old leaves against cutting by the leaf-cutting ants *Atta cephalotes* (L.) and *Acromyrmex octospinosus* (Reich) (Hymenoptera: Formicidae). Bull. ent. Res. 68, 263-271.

Lizon, P. (1972). Verbreitung der Arten *Sarcoscypha coccinea* (Jacq. ex. S.F. Gray) Lamb. und *Bulgaria inquinans* (Pers. ex Hook.) Fr. in der Slowakei. Ceská Mykol. 26, 149-154.

Merlin, J. & Pasteels, J.M. (1990). La pullulation des cochenilles pulvinaires en milieu urbain: état de la situation et moyens de lutte. In Actes du colloque "Gérer la nature?" Trav. Cons. Nat. 15/2, 607-618.

Merlin, J., Gregoire, J.-C., Dolmans, M., Speight, M.R., Pasteels, J.M. & Verstraeten, C. (1988). Preliminary comparison of two scale insect species on broad-leaved trees in western Europe. Med. Fac. Landbouww. Rijksuniv. Gent 53(3a), 1153-1158.

Nageleisen, L.-M. (1992). Les insectes ravageurs du frêne, de l'érable et du merisier. Rev. for. fr. 44 (suppl.), 121-126.

Nikusch, I.W. (1992). Die Platanennetzwanze, *Corythuca ciliata* Say, und die Rhododendronzikade, *Graphocephala coccinea* Forster, zwei neuere sich ausbreintende Problemschädlinge für das öffentliche Grün in Deutschland. Gesundte Pflanzen 44, 311-315.

Parry, W.H., Edwards, I.D. & Jenkins, T.A.R. (1989). Chemical control of sycamore aphid, *Drepanosiphum platanoidis* (Schr.), with organophosphorus and soap insecticides. Crop Protection 8, 30-36.

Redfern, M. & Askew, R.R. (1992). Plant galls. Richmond Publishing, Slough.

Verstraeten, C. & Merlin, J. (1989). Les cochenilles pulvinaires: des insectes mal connus et dangereux. Espaces Verts 2, 15-21.

Warrington, S. & Whittaker, J.B. (1985). An experimental field study of different levels of insect herbivory induced by *Formica rufa* L. predation on sycamore (*Acer pseudoplatanus*). 2. Aphidoidea. J. appl. Ecol. 22, 787-796.

Warrington, S., Cottam, D.A. & Whittaker, J.B. (1989). Effects of insect damage on photosynthesis, transpiration and $SO_2$ uptake by sycamore. Oecologia 80, 136-139.

Wellings, P.W., Chambers, R.J., Dixon, A.F.G. & Aikman, D.P. (1985). Sycamore aphid numbers and population density. 1. Some patterns. J. Anim. Ecol. 54, 411-424.

Wellings, P.W. & Dixon, A.F.G. (1987). Sycamore aphid numbers and population density. 3. The role of aphid-induced changes in plant quality. J. Anim. Ecol. 56, 161-170.

Wulf, A. (1990). Uber die Bedeutung von *Diplodina acerina* (Pass.) Sutton und anderen Blattpilzen als Antagonisten der Fenstergallmucke Dasineura vitrina Kffr. an Bergahorn (*Acer pseudoplatanus* L.). Nachrichtenb. Dt. Pflanzenschutzd. 42, 65-70.

Watt, A.D., Lindsay, E., Leith, I.D., Fraser, S.M., Docherty, M., Hurst, D.K., Hartley, S.E. & Kerslake, J. (1996). The effect of climate change on the winter moth, *Operophtera brumata*, and its status as a pest of broadleaved trees, Sitka spruce and heather. Asp. appl. Biol. 45, 307-316.

### 7.2.5 Vertebrate pests

Abbott, R.J., Bevercombe, G.P. & Rayner, A.D.M. (1977). Sooty bark disease of sycamore and the grey squirrel. Trans. Br. mycol. Soc. 69, 507-508.

Burgess, J.M. (1957). Damage to bark of sycamore by grey squirrels. J. Oxf. Univ. Forest Soc. Ser. 4 (5), 15-16.

Kenward, R.E. (1981). Grey squirrel damage and management. In Last, F.T. & Gardiner, A.S. (Eds) Forest and woodland ecology, pp. 132-134. Institute of Terrestrial Ecology, Cambridge.

Kenward, R.E. (1982). Bark-stripping by grey squirrels - some recent research. Quart. J. For. 76, 108-121.

Kenward, R.E. (1989). Bark-stripping by grey squirrels in Britain and North America: why does the damage differ. In Putman, R.J. (Ed.) Mammals as pests, pp. 144-154. Chapman & Hall, London.

Kenward, R.E. & Dutton, J.C. (1996). Damage by grey squirrels. 2. The value of prediction. Quart. J. For. 90, 211-218.

Kenward, R.E., Parish, T. & Doyle, F.I.B. (1988). Grey squirrel bark-stripping. 2. Management of woodland habitats. Quart. J. For. 82, 87-94.

Kenward, R.E., Parish, T., Holm, J. & Harris, E.H.M. (1988). Grey squirrel bark-stripping. 1. The role of tree quality, squirrel learning and food abundance. Quart. J. For. 82, 9-20.

Kenward, R.E., Dutton, J.C.F., Parish, T., Doyle, F.I.B., Walls, S.S. & Robertson, P.A. (1996). Damage by grey squirrels. 1. Bark-stripping correlates and treatment. Quart. J. For. 90, 135-144.

Middleton, A.D. (1931). The grey squirrel. Sidgwick & Jackson, London.

Middleton, A.D. (1931). Damage to forests by squirrels. Quart. J. For. 25, 317-326.

Rowe, J.J. (1984). Grey squirrel (*Sciurus carolinensis*) bark-stripping damage to broadleaved trees in southern Britain up to 1983. Quart. J. For. 78, 230-236.

Rowe, J.J. & Gill, R.M.A. (1985). The susceptibility of tree species to bark-stripping damage by Grey squirrel (*Sciurus carolinensis*) in England and Wales. Quart. J. For. 78, 183-190.

Shorten, M. (1951). Some aspects of the biology of the grey squirrel (*Sciurus carolinensis*) in Great Britain. Proc. Zool. Soc. Lond. 121, 427-459.

Shorten, M. (1951). Damage caused by squirrels in the Forestry Commission areas, 1954-6. Forestry 30, 151-172.

Lüpke, B.V. (1978). Einfluss unterschiedlicher Pflanzensortimente auf die Entwicklung von *Fraxinus excelsior* und *Acer pseudoplatanus* Pflanzbestände. In Oswald, H. (Ed.) Symposium on establishment and treatment of high-quality hardwood forests in the temperate climatic zone, pp. 192-196. Station de Sylviculture et de Production No. 78/08, Nancy-Champenoux.

Miegroet, M. van (1956). Untersuchungen über den Einfluss der waldbaulichen Behandlung und der Umweltsfaktoren auf den Aufbau und die morphologischen Eigenschaften von Eschendickungen im schweizerischen Mittelland. Mitt. schweiz. Anst. forstl. VersWes. 32, 229-370.

Miegroet, M. van (1962). Considération sur le problème du traitement des forêts de petite superficie. Bull. Soc. r. for. Belg. 69, 437-456.

Mlinsek, D. & Ferlin, F. (1992). Waldentwicklung in der Jugend und die Kernfragen der Waldpflege. Schweiz. Z. Forstwes. 143, 983-990.

Mosandl, R. (1991). Die Steuerung von Waldökosystemen mit waldbaulichen Mitteln - dargestellt am Beispiel des Bergmischwaldes. Mitt. Staatforstverwaltung Bayerns 46, 1-246.

Moser, O. (1995). Umwandlung unstandortsgemässer Fichtenbestände in naturnahe Mischwälder im Bereich der Forstverwaltung Bad Goisern der Österreichischen Bundesforste. Cbl. Gesamte Forstw. 112, 33-51.

Nagel, J. (1986). Wachstumsmodell für Bergahorn in Schleswig-Holstein. Allg. Forst- Jagdztg 157, 31-36.

Orde-Powlett, N.A. (1923). The silvicultural treatment of sycamore. Quart. J. For. 17, 252-254.

Pryor, S.N. & Savill, P.S. (1986). Silvicultural systems for broadleaved woodland in Britain. Oxf. For. Inst. Occ. Papers 32, 1-47.

Rausch, H. (1983). Bewirtschaftung des Bergahorns im Forstamt Dierdorf. Allg. Forstz. 33/34, 858-860.

Röhrig, E. (1978). Bestandspflege bei Esche und Ahorn. In Oswald, H. (Ed.) Symposium on establishment and treatment of high-quality hardwood forests in the temperate climatic zone, pp. 219-226. Station de Sylviculture et de Production No. 78/08, Nancy-Champenoux.

Sabroe, A.S. (1973). Plukhugstagtig behandling af lovtræblandskov. Dansk Skovforen. Tidsskr. 58, 201-218.

Savill, P.S. (1991). The silviculture of trees used in British forestry. CAB International, Wallingford.

Schrötter, H. (1975). Waldbauliche Bedeutung und Behandlung des Bergahorns (*Acer pseudoplatanus* L.) im Jungpleistozän der DDR. Beitr. Forstwirtsch. 9, 92-97.

Schrötter, H. (1978). Die Edellaubhölzer in Waldbau und Forsteinrichtung. Beitr. Forstwirtsch. 12, 114-122.

Schütz, J.-P. (1990). Sylviculture. 1. Principes d'éducation des forêts. Presses Polytechniques et Universitaires Romandes, Lausanne.

Schütz, J.-P. (1992). Die waldbaulichen Formen und die Grenzen der Plenterung mit Laubbaumarten. Schweiz. Z. Forstwes. 143, 442-462.

Smart, G.F. (1962). Natural regeneration of hardwoods with profit. Quart. J. For. 56, 160-163.

Spellmann, H. (1981). Zum Wachstum des Bergahorns in Dänemark. Forst- Holzwirt. 36, 201-207.

Stern, R.C. (1982). The use of sycamore in British forestry. In Malcolm, D.C., Evans, J. & Edwards, P.N. (Eds) Broadleaves in Britain. Future management and research, pp. 83-87. Institute of Chartered Foresters, Edinburgh.

Stern, R.C. (1989). Sycamore in Wessex. Forestry 62, 365-382.

Stevenson, G.F. (1985). The silviculture of ash and sycamore. In National Hardwood Programme, pp. 25-31. Commonwealth Forestry Institute, Oxford.

Thill, A. (1975). La sylviculture des feuillus dits secondaires. Notes tech. Cent. Ecol. for. rurale 27, 1-10.

Kegler, H., Fuchs, E., Knapp, H.D. & Ehrig, F. (1994). [Investigations on the evidence of plant pathogenic viruses in the nature reserve of the island Vilm.] Archiv. Phytopath Pl. Prot. 29, 211-216.

Kerr, G. (1995). Silviculture of ash in southern England. Forestry 68, 63-70.

Kowalski, T. & Kehr, R.D. (1992). Endophytic fungal colonization of branch basses in several forest tree species. Sydowia 44, 137-168.

Lanier, L., Joly, P., Bandoux, P. & Bellemère, A. (1976). Mycologie et pathologie forestière. Tome 2. Pathologie forestière. Masson, Paris.

Pawsey, R.G. (1983). Ash dieback survey, summer 1983. C.F.I. Occ. Paper 24.

Schwarze, F.W.M.R., Lonsdale, D. & Fink, S. (1995). Soft rot and multiple T-branching by the basidiomycete *Inonotus hispidus* in ash and London plane. Mycol. Res. 99, 813-820.

### 7.3.3 Insect pests

Chararas, C. (1958). Observations sur la biologie de *Leperesinus fraxini* Panz, (Col.) Scolytidae. Rev. Path. Veget. ent. agric. Fr. 37, 199-215.

Foggo, A. (1996). Patterns of herbivory by the ash bud moth *Prays fraxinella*: implications for the silviculture of ash in Europe. Forest Ecol. Mgmt 84, 231-240.

Foggo, A. (1996). Long- and short-term changes in plant growth following simulated herbivory: adaptive responses to damage? Ecol. Entomol. 21, 198-202.

Foggo, A. & Speight, M.R. (1993). Root damage and water stress: treatments affecting the exploitation of the buds of common ash *Fraxinus excelsior* L., by larvae of the ash bud moth *Prays fraxinella* Bjerk. (Lep., Yponomeutidae). Oecologia 96, 134-138.

Foggo, A. & Speight, M.R. (1995). Factors affecting choice of buds by larvae of the ash bud moth *Prays fraxinella* Bjerk. (Lep., Yponomeutidae), and the implications for ash dieback. J. appl. Entomol. 119, 29-34.

Foggo, A., Speight, M.R. & Grégoire, J.-C. (1994). Root disturbance of common ash, *Fraxinus excelsior* (Oleaceae), leads to reduced foliar toughness and increased feeding by a folivorous weevil, *Stereonychus fraxini* (Coleoptera, Curculionidae). Ecol. Entomol. 19, 344-348.

Hull, S.K. (1991). A study undertaken in southern Britain to investigate the late-flushing of hedgerow ash in Spring 1987. Forestry 64, 189-197.

Lemperière, G. & Malphettes, J.-C. (1983). Observations sur l'écologie de deux coléoptères ravageurs du frêne - *Leperesinus fraxini* Panz, (Coleoptera, Scolytidae), *Stereonychus fraxini* De Geer (Coleoptera, Curculionidae). Rev. for. fr. 35, 283-288.

### 7.3.4 Vertebrate pests

Greig-Smith, P.W. (1988). Bullfinches and ash trees. Assessing the role of plant chemicals in controlling damage by herbivores. J. Chem. Ecol. 14, 1889-1903.

Greig-Smith, P.W. & Wilson, M.F. (1985). Influence of seed size, nutrient composition and phenolic content on the preferences of bullfinches feeding on ash trees. Oikos 44, 47-54.

Nageleisen, L.-M. (1992). Les insectes ravageurs du frêne, de l'érable et du merisier. Rev. for. fr. 44 (suppl.), 121-126.

Newton, I. (1967). The feeding ecology of the bullfinch (*Pyrrhula pyrrhula* L.) in southern England. J. Anim. Ecol. 36, 721-744.

Newton, I. (1972). Finches. Collins, London.

Matthews, N.J. & Flegg, J.J.M. (1981). Seeds, buds and bullfinches. In Thresh, J.M. (Ed.) Pests, pathogens and vegetation, pp. 375-383. Pitman, Boston.

Summers, D.D.B. (1981). Bullfinch (*Pyrrhula pyrrhula*) damage in orchards in relation to woodland bud and seed feeding. In Thresh, J.M. (Ed.) Pests, pathogens and vegetation, pp. 385-391. Pitman, Boston.

Schwenke, W. (1972, 1974, 1978, 1982). Die Forstschädlinger Europas, Band 1, 2, 3 & 4. Parey, Hamburg.

Thill, A. (1978). La sylviculture du frêne en Belgique. In Oswald, H. (Ed.) Symposium on establishment and treatment of high-quality hardwood forests in the temperate climatic zone, pp. 207-218. Station de Sylviculture et de Production No. 78/08, Nancy-Champenoux.

Thill, A. & Mathy, P. (1980). La culture des essences précieuses en Belgique. Annls Gembloux 86, 1-32.

Wagenhoff, A. (1975). Die Wirtschaft in Edellaubholz/Buchen-Mischbeständen auf optimalen Standorten im Forstamt Bovenden. Aus dem Walde 24, 5-60.

### 7.3.6 Ecotypes and races

Asche, N. (1995). Die Esche. Allg. Forst Z. 50, 1087-1089.

Bovet, J. (1958). Contribution à l'étude des "Races écologiques" du frêne, *Fraxinus excelsior* L. Schw. Z. Forstw. 109, 536-546.

Grozdov, B.V. (1945). O Brjanskoí botanicyeskoí 'anomalii'. Bot. Zurn. 30, 178-184.

Helliwell, D.R. (1982). Silviculture of ash (*Fraxinus excelsior*) in Wessex. Quart. J. For. 76, 103-108.

Kalela, A. (1937/38). Zur Synthese der experimentellen Untersuchungen über Klimatrassen der Holzarten. Comm. Inst. For. Fenniae 26, 1-445.

Kerr, G. (1995). Silviculture of ash in southern England. Forestry 68, 63-70.

Leibundgut, H. (1956). Beitrag zur Rassenfrage bei der Esche. Schweiz. Z. Forstwes. 107, 165-174.

Marinov, I. (1969). Pl'tnost na d'rvesinata pri njakoi formi na obiknovenija jasen (*Fraxinus excelsior* L.) v *severoizpochna* B'lgariya. Nauka, Sofia 6(5), 57-63.

Moulalis, D. (1974). Possibilities of the existence of races associated with soil types within forest tree species. Dasos 26(65/66), 16-20.

Münch, E. & Dieterich, V. (1925). Kalkesche und Wasseresche. Forstl. Wschr. Silva 13, 129-135.

Schönborn, A. von (1967). Gibt es Bodenrassen bei Waldbäumen? Allg. Forstz. 22(18), 294-296.

Weiser, F. (1964). Beitrag zum Problem der sog. Bodenrassen bei unsern Waldbaumarten, unter besonderer Berücksichtung der Esche, *Fraxinus excelsior* L. Forstw. Cbl. 83, 23-33.

Weiser, F. (1964). Anlage und erste Ergebnisse vegleichender Anbauversuche mit generativen Nachkommenschaften von Esche (*Fraxinus excelsior* L.) trockener Kalkstandorte und grundwasserbeeinflusster Standorte. Forstw. Cbl. 83, 193-201.

Weiser, F. (1995). Beitrag zur Existenz von Ökotypen bei Gemeiner Esche (*Fraxinus excelsior* L.). Forstarchiv 66, 251-257.