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DUTCH ELM DISEASE IN BRITAIN,

by John Gibbs, Clive Brasier and Joan Webber

Summary

Dutch elm disease is one of the most serious tree diseases in the world and the elms of Britain have suffered severely. It is caused by two related species of fungi in the genus *Ophiostoma* which are disseminated by various elm bark beetles. Much is now known about the history of the disease and about factors influencing its severity. Some new approaches to control have been identified.

Introduction

In the 1970s, Dutch elm disease caused a major environmental disaster when it killed millions of elms in southern Britain. Now after some 20 years the disease is reappearing in elms that have grown up in the aftermath of that epidemic. At the same time the disease is continuing to make inroads into the remaining elm populations of northern Britain. This Note provides an introduction to the history, status and biology of the disease and describes briefly the various approaches to control. A selection of literature references is provided.

History and distribution of the disease

Dutch elm disease was recorded in a number of European countries shortly after the first world war. In the British Isles it was first identified in Hertfordshire during 1927 although it was certainly present some years earlier. There is recent evidence that the disease may have come originally from the Himalayas (Brasier, 1990; 1994); the name 'Dutch elm disease' merely reflects the considerable early research carried out in the Netherlands. In parts of southern England the disease at first caused widespread death of elms, but in the 1940s it declined both in terms of the number of trees affected and in the severity of damage caused. Thereafter, although locally severe 'flare-ups' were not infrequent, Dutch elm disease came to be regarded as an endemic problem of no great importance (Peace, 1960). In the late 1960s however, a new epidemic developed causing devastation on a scale far greater than before. It is estimated that by 1980 over 20 million elms had been killed. By this time the disease had caused major losses throughout England and Wales and was also present in the central lowlands of Scotland (Redfern, 1977). Subsequently, it has extended its range northwards in Scotland although it is not known to be present along the Moray Firth or north of the Great Glen.

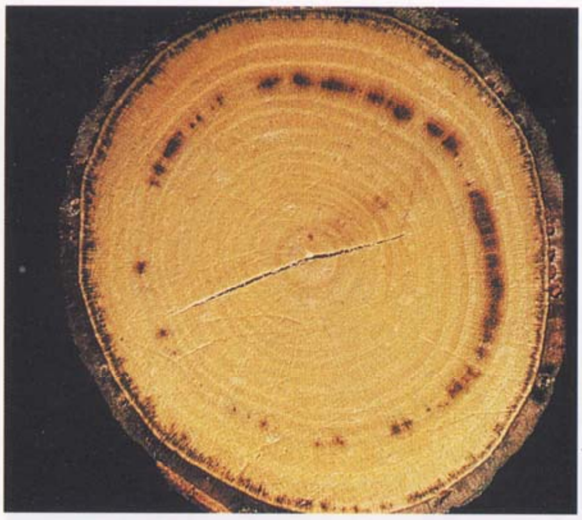
This recent epidemic of Dutch elm disease is not a purely British phenomenon; it has also caused enormous damage elsewhere in Europe, in south-west and central Asia and in North America (see Gibbs, 1978). Indeed, the disease is widespread throughout the natural distribution of elm with the exceptions of China and Japan. Dutch elm disease has also recently been recorded in New Zealand where elm is an introduced species.

Symptoms of the disease

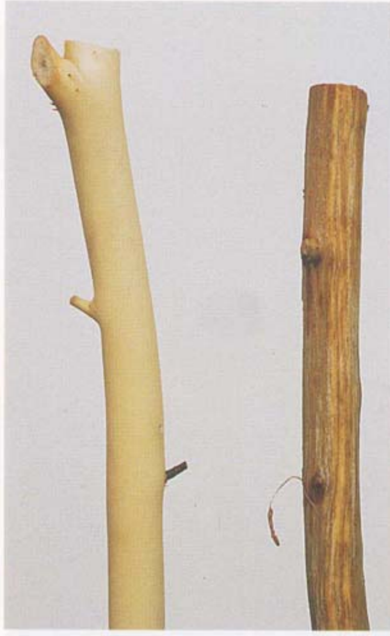
The first sign of the disease is often a yellowing or browning of the foliage on part of the tree, sometimes giving the appearance of scorching (Front cover). Affected branches begin to die back from the tip, the twigs sometimes turning down as they die to form little 'shepherds' crooks' which persist and are of some value in detecting diseased trees during the winter. In a severe attack, the entire tree is often killed before the end of the summer; but even if it survives it may well die in the following spring.

If twigs from the affected part of a tree are cut in cross section, they show dark brown spots in the outer wood, often in sufficient number to form a definite ring (Figure 1). If the bark and a few shavings of the outer wood are removed from an affected branch, longitudinal brown streaks of varying lengths can be seen (Figure 2). These correspond with the brown spots observed in cross-section. The markings may not be evident in all the branches that are dying back; this is especially the case with lower branches of large trees.

Front cover: Foliage symptoms on English elm with (inset) bark removed from dead tree showing breeding galleries of *Scolytus scolytus*.

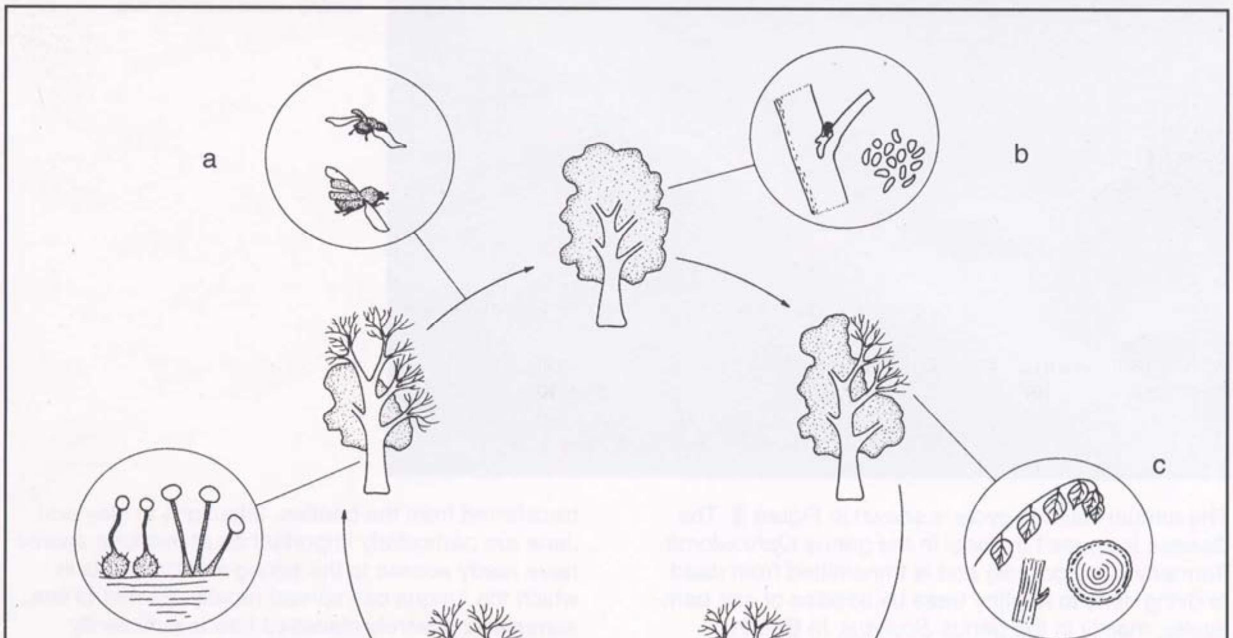


▲ Figure 1: Dutch elm disease stain in the wood. This photograph, taken in 1970, shows evidence some distance into the wood of an infection from which the tree must have recovered (probably caused by *O. ulmi*), and an infection in the outermost wood from which the tree died (certainly caused by *O. novo-ulmi*).



◄ Figure 2: Diseased twig with bark removed to show stain just below surface of xylem. Healthy twig on left.

The disease cycle



▲ Figure 3: Life cycle of fungus and beetle:

a) Adult beetles emerge in spring and summer from the bark of dead and dying elms carrying spores of the causal fungus.
b) They feed in the twig crotches of healthy elms and introduce fungal spores into the wood.
c) As a result the infected parts wilt and diseased twigs show characteristic dark streaks or spots.
d) Trees weakened by disease become breeding sites for beetles.
e) The larvae develop galleries within the bark.
f) The fungus fruits in the pupal chambers.

◀ Figure 4: Outer-bark of dead tree pared away to show mature beetle larvae in pupal chambers.

▲ Figure 6: Root transmission through a hedgerow of English elm.

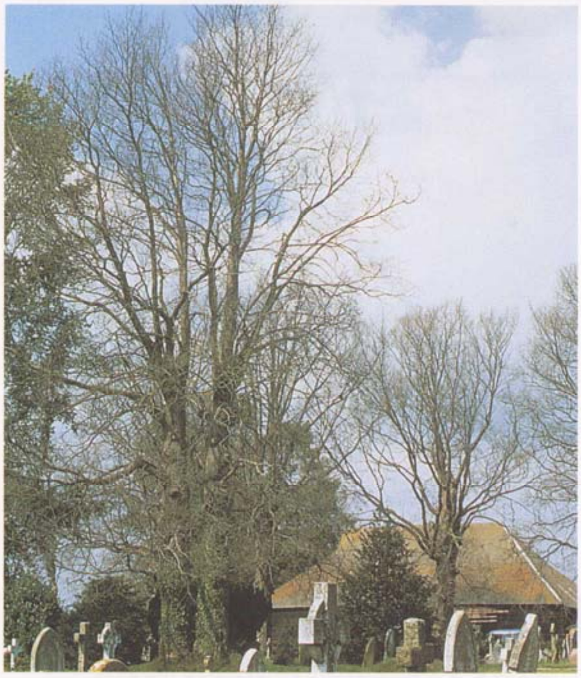
◀ Figure 5: Bark-beetle maturation feeding wound in an elm twig.

The annual disease cycle is shown in Figure 3. The disease is caused by fungi in the genus *Ophiostoma* (formerly *Ceratocystis*) and is transmitted from dead or dying elms to healthy trees by species of elm bark beetle, mainly in the genus *Scolytus*. In Britain, during summer and early autumn, adult female beetles bore into the inner bark of moribund elms, tunnel out a breeding gallery and lay their eggs at intervals along its length. The resultant larvae make secondary tunnels starting at right-angles to the mother gallery (Front cover). Sometimes the arrangement remains quite distinct and a regular fan-like pattern is formed, but often the galleries become confused. The beetles pupate in the bark or outer sapwood (Figure 4) and emerge as young adults during the following spring, making small circular holes, so that an affected stem appears to have been peppered with small shot. These young adults carry spores of the fungus on their bodies, having become contaminated while lying in the pupal chambers. Before breeding, they often fly into the crowns of healthy elms to feed on bark in the forks between twigs. This feeding creates a groove, often into the sapwood (Figure 5) and, in the process, the damaged tissue may become infected with spores transferred from the beetles. Infections in May and June are particularly important as at this time spores have ready access to the spring-wood vessels in which the fungus can spread rapidly. By mid to late summer, a severely diseased tree is sufficiently weakened to allow beetle colonisation of the bark to occur and thus the disease cycle is completed.

For long-distance spread the fungus is dependent upon the bark beetles but it can also pass via the xylem of interconnected roots from diseased to adjacent healthy trees (Figure 6). This type of disease transmission is particularly important for those types of elm that arise as root suckers and are, in consequence, linked through their root systems. However it can also occur when the roots of neighbouring trees have grafted together.

Following death from Dutch elm disease, large elms can remain suitable for beetle breeding for up to two years, although the thinner bark of smaller trees is likely to become unsuitable after just a year. Once the bark is dead, it is no longer attractive to breeding beetles and the tree then ceases to have any further significance for the epidemiology of the disease.

The fungus



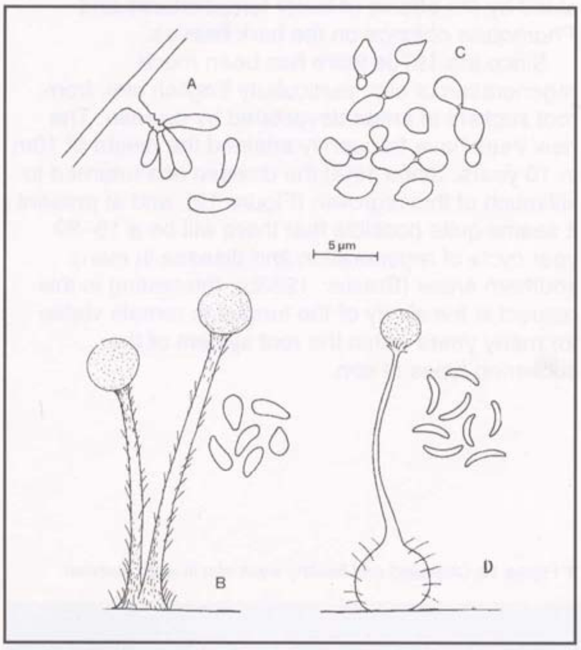
▲ Figure 7: English elm killed in the 1970s' epidemic.

The 1970s' epidemic resulted from the introduction to Britain of a very pathogenic form of the Dutch elm disease fungus on diseased elm logs imported from Canada (Figure 7). This form of the fungus has recently been named *Ophiostoma novo-ulmi* to distinguish it from *Ophiostoma ulmi,* the less pathogenic fungus which was responsible for the 1930s' epidemic. The two species can be separated in the laboratory by their different appearance and physiological attributes (Brasier, 1991). *O. novo-ulmi* exists as two races, each of which has had a different history of spread within the Northern Hemisphere (Brasier, 1990).

The two species behave in a similar way. Following infection, the fungus exists in the living tree as a yeast-like stage (Figure 8c), which is carried along in the sap of the vessels of the outermost xylem ring. The mechanism by which infection leads to the appearance of the wilting symptoms is far from understood, but fungal toxins are certainly involved. In addition the fungus can cause vessels to fill with air and this is followed by the production in the vessels of tyloses, gummy extensions of the xylem wall. These accumulate to form the dark streaks that are visible on cutting infected twigs.

The fungus also colonises the bark of dead or dying elms during the breeding activities of the bark beetles. It grows as a mycelium and can produce two asexual fruiting structures (Figures 8a and b) in the beetle galleries and in spaces under loosened bark. The flask-like perithecium or sexual stage (Figure 8d) is formed in similar locations. The fungus has two mating types, A and B, and both must be present for fertile perithecia to form.

During the last 20 years a great deal has been learnt about the many factors involved in the parasitic and saprotrophic stages of the fungus and their impact on disease transmission (Webber and Brasier, 1984; Webber *et al.*, 1988). Of particular interest has been the discovery that the fungus can be affected by a virus-like agent, the 'd-factor', which can reduce its ability to colonise and reproduce (Brasier, 1983a; Webber, 1993).



◀ Figure 8: Spore forms and fruit bodies of the *Ophiostoma ulmi* and *O. novo-ulmi.* The scale applies to the spores only:
a) conidial or *Sporothrix* stage
b) stalk-like coremium (*c.* 1 mm tall) and coremiospores
c) budding yeast-like stage
d) flask-shaped perithecium (0.5 mm tall) and ascospores.

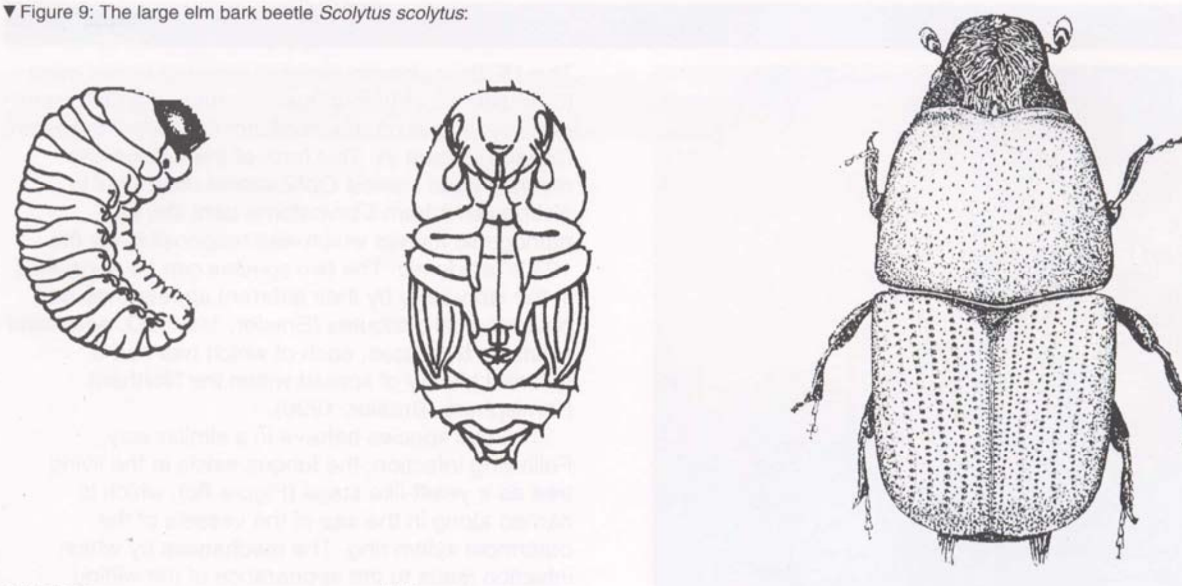
The elm bark beetles

Two species of scolytid beetles are principally concerned with Dutch elm disease transmission in Britain. Both have a shiny black thorax and dark red-brown wing cases. The large European elm bark beetle, *Scolytus scolytus,* is 5–6mm long (Figure 9) and the small European elm bark beetle, *S. multistriatus,* 2.5–3.5mm long. *S. scolytus* is much the more important vector: the adult beetle carries a far greater number of spores than does *S. multistriatus* and makes wounds that are more conducive to infection of the xylem (Webber and Brasier, 1984). In addition, *S. scolytus* is the only species capable of breeding successfully in Scotland and parts of northern England. Here it has a single generation each year, but further south there may be a second or even a partial third generation.

S. multistriatus typically has only one generation each year (Fairhurst and King, 1983; Fairhurst and Atkins, 1987). For flight, the adult beetles require air temperatures of at least 18°C. Beetles are attracted to suitable breeding material by an 'aggregation pheromone' produced by the first beetles to colonise the bark.

Many agents act to reduce the number of beetle larvae in the breeding galleries. They include predators such as woodpeckers, fungal pathogens and parasitic hymenopteran wasps. In addition, the fungus *Phomopsis oblonga* growing in the bark can prevent successful breeding. Under epidemic conditions, however, such a vast amount of breeding material is created that these various agents have little effect upon the spread of disease.

▼ Figure 9: The large elm bark beetle *Scolytus scolytus*:



a) the larva b) the pupa c) the adult.

The elm population and its susceptibility to disease

The elm population of Britain is very diverse (Richens, 1983). In the upland north and west of the country the native wych elm, *Ulmus glabra,* occurs. It sets seed abundantly but does not reproduce by suckering. In the lowlands its place is taken by various types of smooth leaved or field elm, *U. minor* Sensu lato (syn. *U. carpinifolia*). Included among these is the English elm, which is sufficiently distinctive to have been given the separate Latin name of *U. procera.* There is evidence that all these lowland elms were introduced to Britain before the Roman invasion by immigrating tribes which *inter alia* prized them for the value of the foliage for fodder. Smooth leaved elms (including *U. procera*) do not normally set fertile seed in this country, but readily produce suckers. Hybridisation between wych and certain smooth leaved elms is thought to have occurred occasionally, giving rise to distinct types such as the Huntingdon elm *U.* x *vegeta.* From the eighteenth century onwards elms became increasingly important as hedgerow trees. They were also extensively planted in both rural and urban parks, and certain types, such as the Wheatley elm (*U. minor* var. *sarniensis*) were favoured for roadside planting.

All these elms are susceptible to the disease (Figure 10), although differences do exist between them. Thus, some large Huntingdon elms still survive in places in lowland England where all other large elms have been killed. Similarly a significant number of *U. minor* var. *minor* survive more or less unaffected by the disease in parts of eastern England (Figure 11). Experiments have shown that wych elm is relatively unattractive to the elm bark beetle for feeding and this can explain its better survival rates in certain areas. Also, because it does not reproduce by suckering, it is less prone to infection via root transmission. In northern Britain its survival is further aided by the effects of lower temperatures and *Phomopsis oblonga* on the bark beetles.

Since the 1970s there has been much regeneration of elm, particularly English elm, from root suckers in areas devastated by disease. The new trees have frequently attained the height of 10m in 10 years. Since 1990 the disease has returned to kill much of this regrowth (Figure 12), and at present it seems quite possible that there will be a 15–20 year cycle of regeneration and disease in many southern areas (Brasier, 1983b). Interesting in this respect is the ability of the fungus to remain viable for many years within the root system of the suckering types of elm.

▼ Figure 10: Diseased and healthy wych elm in early summer.

▲ Figure 11:
Surviving *Ulmus minor* var. *minor* in Cambridgeshire photographed in July 1993. The long-dead trees are almost certainly from a different and more susceptible type of elm.

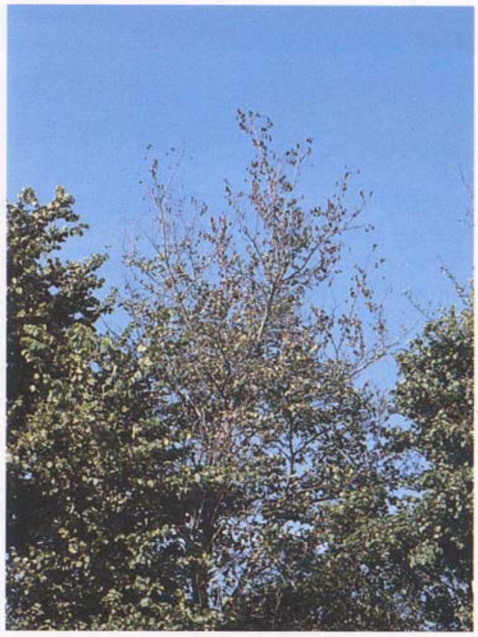


Figure 12: ▶
Disease in English elm regeneration, summer 1992.

Control measures

Sanitation felling

When the 1970s' epidemic of the disease began in Britain, sanitation felling programmes were instituted. Continuing operations are maintained in a few localities, supported by the Dutch Elm Disease (Local Authorities) Order. Control through sanitation relies on the felling of diseased trees and the destruction of the bark to eliminate beetle breeding material. Bark on logs from healthy trees must also be destroyed if beetle breeding is to be contained. As an adjunct to sanitation control, in some situations it is also vital to prevent spread of the disease through root systems. This can be achieved by mechanical severance of the connecting roots or by killing a narrow band of roots with a soil fumigant. To be successful, a sanitation control programme requires a major commitment of effort and resources sustained over many years and is usually most appropriate in urban areas (Greig and Gibbs, 1983).

Control of the bark beetles

In the past much effort was directed to the use of insecticides to protect healthy elms from feeding by bark beetles. Subsequently, this approach was abandoned on grounds of ineffectiveness and environmental damage. Attention was then directed to the search for attractants which could be used in beetle-trapping operations (see Grove, 1983). This approach has also been given up, although pheromone traps have proved to be a useful method of monitoring beetle populations in sanitation control areas (Fairhurst and Atkins, 1987). Bark beetles are not good candidates for biocontrol with the kind of fungal or bacterial preparations that have worked well with other insects.

Control of the fungus

Considerable effort has been expended in the development of systems of fungicide injection which could combat the disease in valuable trees during the early stages of infection. During the 1970s a successful system involving a soluble formulation of the fungicide thiabendazole was devised (see Greig, 1986). It was, however, a costly operation and marketing considerations eventually led to the withdrawal of the fungicide solution. A wide variety of other materials, including biocontrol agents, have been investigated over the years but without success (Brasier and Webber, 1987).

Reference has already been made to the virus-like 'd-factor' and its deleterious effect upon the fungus. Many different d-factors have been discovered within populations of both *O. ulmi* and *O. novo-ulmi,* and current research is directed towards finding ways in which these can be harnessed in the bio-control of the disease (Webber, 1993). This is seen to be especially important in relation to the long term future of *U. minor* and *U. procera* in the countryside, where populations of trees are continually renewing themselves by sucker growth.

Breeding for resistance

Although elms differ in their resistance to the beetle as well as to the fungus (Webber and Kirby, 1983), elm breeding programmes have focused on achieving resistance to the fungus; this despite the fact that the resistance mechanisms involved are poorly understood (Duchesne, 1993). A high level of resistance to the fungus is present in some Asian species of elm such as *Ulmus pumila* and *U. parvifolia.* However these are entirely different in appearance to British elms and would not be acceptable replacements. Work on the selection and breeding of elms for resistance to *O. novo-ulmi* has been carried out in the Netherlands and in Italy, and also in North America. Various clones have been released. These include Groeneveld, Plantyn, Dodoens, Lobel and Clusius from the Research Institute for Forestry and Landscape Planning, The Netherlands (Heybroek, 1983; 1993) and Sapporo Autumn Gold from the University of Wisconsin, USA. However none of these has the right combination of silvicultural and disease resistance qualities to make it suitable for widespread planting. A recent initiative in Britain is an attempt to introduce disease resistance into *U. procera,* the English elm, by genetic engineering.

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