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KEITHIA DISEASE OF THUJA PLICATA

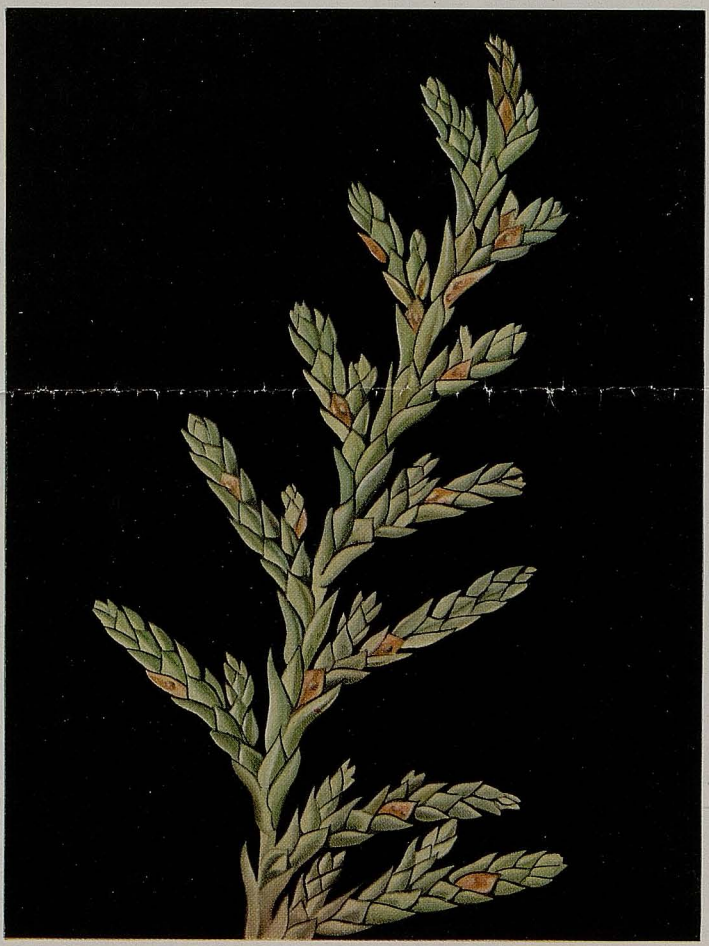

Figure 1. *Didymascella* (*Keithia*) *thujina*. Moderately light attack by the fungus on foliage of *Thuja plicata*, the Western red cedar. The scattered nature of the infection is well shown.

KEITHIA DISEASE OF THUJA PLICATA

Keithia disease, or *Thuja* Needle blight, is caused by the fungus *Didymascella* (*Keithia*) *thujina* (Durand) Maire, and is the most important disease of Western red cedar (*Thuja plicata*) in Britain. Infection by the fungus is confined to the needles, but even moderate attack may lead to the death of whole shoots, probably due to the production of toxic substances by the fungus. Serious infection occurs mostly in nurseries, where it can cause very considerable losses of seedlings and transplants. Hedge plants and trees of all ages are also affected, but on these older plants the damage is seldom serious.

HISTORY OF THE DISEASE

Didymascella thujina occurs naturally in North America on *Thuja plicata* and *Thuja occidentalis* (Northern white cedar). It was first recorded in Europe in 1918 when it was discovered in Ireland, presumably having been introduced on plants imported from America. In 1919, the disease was observed in Sussex and since then it has become widely distributed in Britain and also in most north European countries. In Britain, *Thuja occidentalis* is seldom attacked and on several occasions trees of this species growing in close proximity to heavily infected *Thuja plicata* have been seen to be completely healthy or only very slightly affected.

THE FUNGUS AND DISEASE SYMPTOMS

Didymascella thujina is a member of the Ascomycetes, belonging to the family Phacidiaceae in which the fructification is an apothecium embedded in the host tissue. The apothecium of *Didymascella* appears as a small pustule-like structure, and until maturity it is covered by the needle epidermis. At maturity, when the apothecium is erumpent from the needle surface, the epidermis splits peripherally around the fructification. This exposes the closely packed layer of asci, which are the spore-producing organs and which actively eject the internally produced ascospores a short distance into the air. The asci of *Didymascella thujina* differ from those of most ascomycetous fungi in that they contain only two, rather than eight, ascospores. The ascospores themselves are also unusual, being divided by a cross wall into one large functional cell and one very small abortive cell. The ascospores are thick-walled and dark in colour, and are very resistant to desiccation ; charateristics which enable the spores to be carried long distances through the air by passive wind dispersal, without loss of viability. Each spore is surrounded by a sheath of gelatinous material and adheres very firmly to any surface on to which it alights.

The cushion-like apothecial fructifications which are usually produced on the upper side of the needles are clearly visible to the naked eye. Generally one to three fructifications are produced on each leaf and they vary in shape from spherical to narrowly oval (Figures 2 and 3). The flap of epidermis which is pushed aside at maturity is very characteristic. Mature apothecia, when seen under moist conditions, which is when the ascospores are discharged, are golden-olive in colour, but when the surface of the foliage is dry they appear much darker and the epidermal flap often folds back over the fructification surface. Old inactive fructifications appear as black cavities, but are still quite characteristic. The individual apothecia remain active for several weeks and spore discharge from infected plants can take place from late April to early November.

Under conditions in Britain, the fungus appears to overwinter mainly in the form of ascospores attached to the needle surface. It is probable that the sheltered environment afforded by the crevices between the scale-like needles is an important factor in spore survival. The overwintered ascospores germinate in early April ; the germ tubes produced from the spores penetrate the epidermis and the fungal mycelium then develops in the needle tissue.

The fungus may also remain dormant through the winter in an early or incipient stage of apothecium development in the needle tissue. In the spring these incipient apothecia develop to maturity, producing ascospores at the time of new shoot development.

The initial symptoms of infection are the

Figure 2. A branch of *Thuja plicata*, heavily infected with *Didymascella thujina*, showing mature apothecia and also pustulate early stages of apothecial development over which the epidermis remains unbroken.

Figure 3. *Didymascella* (*Keithia*) *thujina*. Mature fruit bodies of the fungus on scale leaves of *Thuja plicata*. The epidermis has burst above the fructifications. Note the typical epidermal flap above one of the fruit bodies.

browning of individual needles scattered over the shoots (see Figure 1). In a heavy attack the majority of the needles may become infected, but this is due entirely to spore infection and not to mycelial spread from needle to needle. Under such heavy infection conditions, branchlets die back rapidly as described above. The general pattern of disease development is a high level of infection in late April and early May, with a fluctuating level of attack through the summer and autumn, depending on climatic conditions.

Unlike most ascomycete fungi, *Didymascella* does not produce conidial or imperfect fructifications, or at least these have never been recognised. Other fungi which produce small black pycnidial fructifications, particularly species of *Pestalotia*, occur on diseased *Thuja* foliage, but they are completely unrelated to *Didymascella thujina* and colonise moribund leaf tissue.

The symptoms of *Keithia* disease are often confused with the colour changes which commonly take place on *Thuja* foliage in the autumn. This pronounced bronzing, particularly of *Thuja* nursery stock, may occur slowly, or may appear quite suddenly following a sharp drop in temperature. It is entirely due to pigmentation changes in the needle tissue and has no apparent adverse effect on the growth of the plants in the following year. The overall change in colour of the foliage is in marked contrast to the early symptoms of attack by *Didymascella*, where the infected brown needles have a scattered distribution on the branchlets.

THE INCIDENCE AND SEVERITY OF DAMAGE

Infection by *Didymascella* is rarely observed on first-year *Thuja* seedlings. The attack at this stage of growth is usually slight and is generally confined to the juvenile needles produced low on the seedling stem. Older *Thuja* nursery stock, whether seedlings or transplants, can be severely attacked, resulting in very heavy losses and even the complete destruction of the crop. However, in about the fourth or fifth year of growth, *Thuja* develops a much higher degree of resistance to infection. As this change in resistance coincides roughly with the time of planting in the forest, where the conditions for infection are much less favourable, even moderately infected individuals can be used for planting with a good chance of survival. Little is known about the relationship between climate and infection, but it is thought that high humidity conditions around the foliage favour infection. Certainly, very heavy infection can occur in dense, highly humid two-year seedbeds.

IMPORTANT BIOLOGICAL FEATURES IN THE CONTROL OF THE DISEASE

Didymascella thujina is an obligate parasite, i.e. it can only colonise *living* host tissue and cannot grow on dead *Thuja* litter or in the soil, or over the surface of *Thuja* seeds. Because of the inability of the fungus to spread from needle to needle, all infection is effectively confined to individual leaflets.

The gelatinous coat of the ascospores effects a very strong adhesion of the spores to any surface on which they are deposited, and it has been found impossible to remove spores from a surface without rendering them non-viable. Living *Thuja* needles are the only structures in which infection can develop following spore germination, and spores adhering to other surfaces, e.g. to *Thuja* seed coats or to the foliage of other conifer species in a nursery, cannot be transferred, by rain-wash or rainsplash for example, on to *Thuja* foliage.

The thick-walled ascospores can be carried long distances (several miles at least) without loss of viability, but the further *Thuja* nursery stock is from an infection source, the less the chance of the establishment of airborne infection.

Although *Didymascella* attack on older trees is rarely serious, even light infection in plantations and hedges, etc. with the associated production of airborne spores, constitutes an important source of inoculum for really serious infection in nurseries in the locality.

When *Thuja* is raised in a nursery for the first time, and is then sown each year, the level of infection generally builds up slowly until epidemic conditions occur, perhaps four or five years after the introduction of the disease.

In the past, the most effective carriage of the disease has been by the transport of infected transplants from nursery to nursery. In this way infection can be disseminated to several nurseries even though the level of infection in the originating nursery may be so low as to be almost unrecognisable.

CONTROL MEASURES

(a) Thuja Sowing in Isolated Nurseries

Keithia disease may be avoided to some extent by sowing *Thuja* seed in forest nurseries well isolated from any other *Thuja* and into which *Thuja* transplants from other nurseries are never imported. As the disease is not seedborne, the introduction of infection is confined to airborne spores and this is limited by the isolated nature of the nurseries. This method was practised by the Forestry Commission for some time in several nurseries, but eventually all but one became infected. However, isolated sowing can be usefully practised where production of *Thuja* in a nursery is only for a limited period.

(b) Rotation Sowing of Thuja in Isolated Nurseries

This method of control, currently practised by the Forestry Commission, is a natural development of (a) and is basically the linked production of plants from a series of isolated nurseries. The build-up of infection in the nurseries is prevented by the periodic clearance of all *Thuja* stock before resowing. Four and five-year rotations are in use, producing three and four-year-old planting stock respectively. Each rotation serves a large area, for example, the whole of Wales is supplied by one four-year rotation, and only one of the nurseries supplies planting stock for that area in any one year. *Thuja* seed is sown in a yearly sequence in the rotation nurseries. The plants are kept in the same nursery until they reach the prescribed planting age (three years old in England and Wales, and four years old in Scotland), and then that particular nursery is cleared completely of *Thuja* and one year elapses before *Thuja* is again sown. Although a "*Thuja*-free" year is part of each rotation cycle, theoretically resowing could be carried out in the season immediately following lifting, but the delayed sowing safeguards any unforeseen overlap between lifting and sowing. In selecting rotation nurseries the aim has been for isolation of $1\frac{1}{2}$—2 miles from any other *Thuja*. A complete embargo is imposed on the introduction of *Thuja* transplants into rotation nurseries, but the rotation programme in no way interferes with movement of other tree species.

(c) Chemical Control

Effective chemical control of *Didymascella* has been achieved recently with cycloheximide fungicides. These materials have been extensively tested both for fungicidal and phytotoxic activity, but although an effective and safe treatment can now be prescribed, proprietary formulations are not yet generally available in Great Britain. However, cycloheximide fungicides should be marketed in this country shortly and advice on chemical control can be obtained by growers from the Forest Research Station, Wrecclesham, Farnham, Surrey.

Spraying experiments have shown that the most important infection phase, i.e. that following the germination of overwintered ascospores on the surface of *Thuja* foliage, can be largely controlled by a single spray application in late March.

(d) Breeding for Resistance

The inheritance of resistance to infection by *Didymascella* apparently depends on a single gene factor. Work is being carried out in Denmark on the hybridisation of the completely resistant Japanese red cedar (*Thuja standishii*) and *Thuja plicata*, with promising results. In this country, selection is being made of individual trees and transplants of *Thuja plicata* which show apparent resistance under conditions of general heavy infection. By a programme of cross-breeding it is hoped to produce one or more cultivars of Red cedar with good silvicultural characteristics and a high degree of resistance.

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