VIRUS DISEASES OF ORNAMENTAL TREES AND SHRUBS

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Using examples drawn from published and my own unpublished data I will describe what viruses do to hardy nursery stock and how their effects may be minimised.

Although gardeners have known for more than 200 years that variegation in *Jasminum* (Fig. 1) probably results from virus infection, Cane showed in 1720 (3) that the condition was graft transmissible, the subject of plant virology is new to many people. I have therefore prefaced my discussion with some background information on the properties of viruses.

Figure 1. Leaves of *Jasminum officinale* naturally infected with arabis mosiac virus and showing yellow blotch patterns.

Viruses multiply only within living cells where they may be "seen" if magnified at 20,000× or more in an electron microscope. These obligatory parasites rarely kill but necessarily debilitate their hosts by, for example, decreasing photosynthetic efficiency through inducing changes in chloroplast morphology which are, in turn, reflected in superficial alterations to leaf color-symptoms. Another organism (a vector) is normally required to carry a plant virus from one host to another although pollen and/or seed are able to act as vehicles for a few viruses such as those having nematode (eelworm) vectors. Man accidentally and, in some instances, deliberately transmits viruses when using vegetative propagation techniques; diseases attributable to viruses, unlike genetic abnormalities and nutritional or physiological disorders with virus-like symptoms are transmissible by budding, grafting, etc. However, natural graft transmission (mostly root anastomosis) is probably infrequent and insignificant when compared to the virus spreading influences of vectors such as insects, mites, soil-inhabiting fungi or nematodes even though there is a marked virus-vector specificity so that a given vector can transmit one, yet not another virus, with which it shares many other properties.

If studies on viruses were restricted to the naturally susceptible deciduous woody ornamental host, information would be but slowly gathered. Therefore, scientists make isolation from the original host for example, but rubbing expressed foliar sap onto the leaves of glasshouse-grown herbaceous hosts which then serve throughout the year as reservoirs of virus later identified from knowledge of physical, chemical and biological properties. When characterised, viruses are given names which usually indicate the associated symptoms of disease in that host from which the virus was first isolated or most intensively studied, e.g. cherry leaf roll virus (CLRV). However, this name may indicate only one of many possible hosts and it is therefore not surprising to find CLRV naturally infecting, for example, elm, birch, rhubarb and elder in addition to cherry.

INTRODUCTION

Knowledge of viruses which infect food plants is considerable and trees or shrubs grown primarily for fruit have been subjected to close examination over many years. In contrast, with the notable exception of work done in Eastern Europe, (16, 17) few surveys to detect viruses in timber trees or woody ornamentals were made until recently. Despite the comparatively small investment of research time devoted to the study of viruses in these crops, an examination of the scientific literature shows that one or more virus-like diseases has been recognized in some 65 genera from 43 families of trees and ornamental shrubs growing in Europe and North America. A great many of these diseases are reportedly graft-transmissible although their actual causes are unknown. Others are associated with poorly characterised viruses and very few of those viruses having several known physico-chemical properties have been proved to cause the symptoms shown by the woody plants in which they were detected. Perhaps, because they reach high concentrations in hosts they infect and because they have vectors which feed on many different plants, two groups of viruses appear to be particularly prevalent in woody perennials.

One group has aphid vectors and includes viruses such as cucumber mosaic and alfalfa mosaic which have been isolated from one or more individuals of *Buddleia, Caryopteris, Chionanthus, Cornus, Daphne, Euonymus, Hydrangea, Jasminum, Leycestria, Ligustrum, Lonicera, Lycium, Maclura, Magnolia, Nandina, Paulownia, Passiflora, Philadelphus, Romneya, Sambucus* and *Viburnum*, showing symptoms which were usually inapparent or slight. However, information to date suggests that a group of viruses having soil-inhabiting nematode vectors are even more widespread in nursery stock and to illustrate the range of symptoms which these plants may show when virus-infected I will use examples drawn from knowledge of two viruses in particular, arabis mosaic virus (AMV) and cherry leaf roll virus (CLRV).

NEMATODE-BORNE VIRUSES IN TREES AND SHRUBS

Virus-vector nematodes are free-living worms (1-6 mm in length) which typically browse on the outermost cells of roots. Although other nematode genera can ingest virus particles, only four: *Xiphinema, Longidorus, Trichodorus* and *Paratrichodorus* are known to include species able to transmit viruses from infected plants (Table 1). In Europe and North America one or more of the viruses listed in Table 1, or others to which these are closely related, have been detected in each of the following genera: *Acer, Aesculus, Betula, Chamaecyparis, Chionanthus, Cornus, Cupressus, Daphne, Euonymus, Forsythia, Fraxinus, Hedera, Hydrangea, Jasminum, Kerria, Laburnum, Leycestria, Ligustrum, Picea, Populus, Ptelea, Robinia, Rosa, Sambucus, Spiraea, Syringa* and *Ulmus*. Their normal method of spreading necessarily causes infection with these viruses to be initiated via roots where it may go unnoticed.

Table 1. The most important nematode vectors in the United Kingdom and the viruses they carry

Vector	Viruses
Xiphinema diversicaudatum	Arabis mosaic, Strawberry latent ringspot cherry leaf roll
Longidorus attenuatus	Tomato black ring
L. elongatus	raspberry ringspot, tomato black ring
L. macrosoma	raspberry ringspot
Trichodorus and *Paratrichodorus* (more than 10 species)	tobacco rattle, pea early browning

However, it is interesting to note that the only well characterised viruses yet isolated from gymnosperms were nematode-borne and detected in roots of *Chamaecyparis lawsoniana* (9), *Cupressus arizonica* (8) and *Picea sitchensis* (9) having apparently normal foliage. Other isolations from tree roots have been reported but leaves are more usually tested because they show symptoms such as those J.B. Sweet of Long Ashton Research Station and I observed in a range of hardy nursery stock and hedgerow plants (Table 2) naturally infected with AMB. Virus-infected foliage is not noticeably abnormal in all instances — symptom expression may be irregular and partial. Thus only about 1% of naturally AMV infected *Fraxinus excelsior* leaflets had line patterns (Fig. 2) yet virus was present in other leaflets. Similarly, when I tested garden stocks of privet, 280 of 287 plants were infected with AMV but in most instances only part of the foliage showed symptoms.

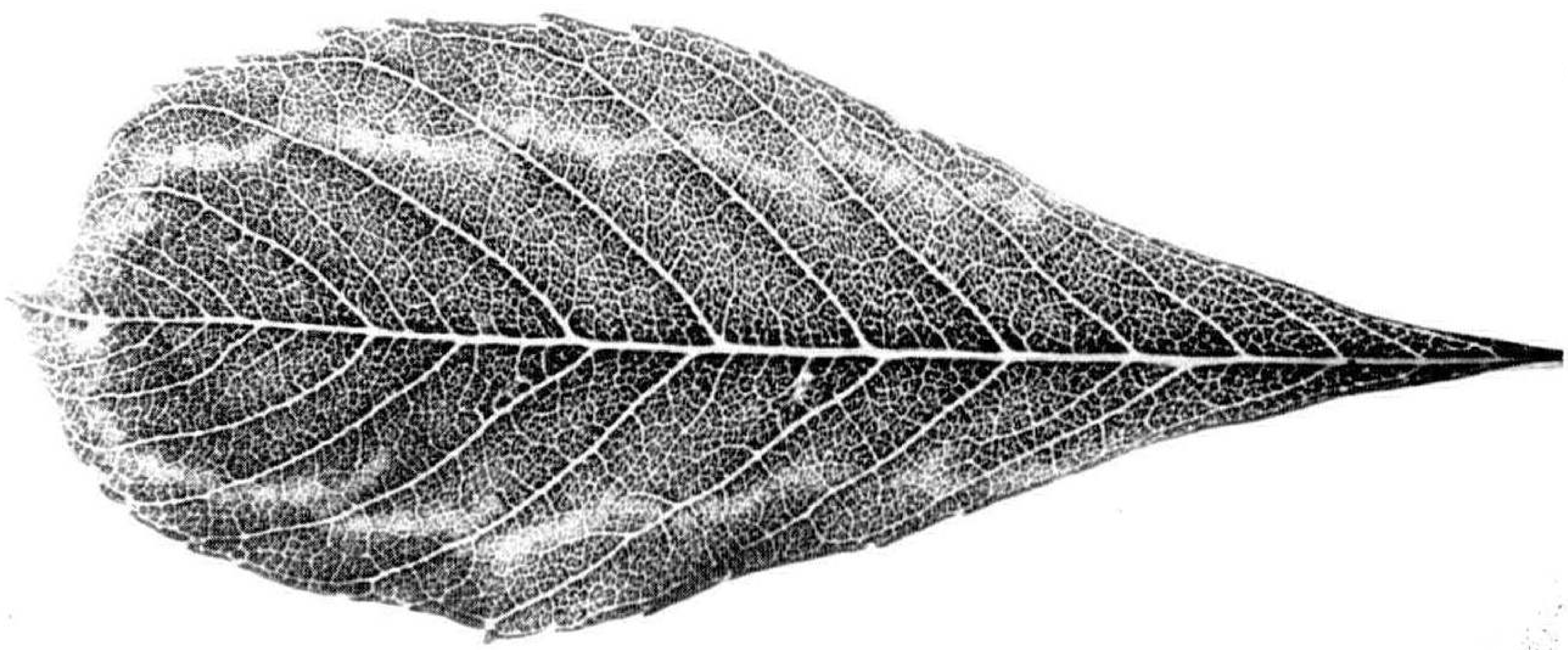

Figure 2. Leaflet of *Fraxinus excelsior* naturally infected with arabis mosiac virus ane showing pale green line patterns.

Table 2. Symptoms in some plants naturally infected with arabis mosaic virus (AMV).

	Host	Leaf Symptom
a) In nurseries and gardens.	*Fraxinus americana**	Yellow-green lines and distortion.
	*Hedera helix**	Yellow blotches and vein banding.
	*Ligustrum ovalifolium**	Pale yellow - green lines or rings.
	*Ligustrum vulgare**	Pale yellow - green lines or rings.
	Spiraea douglasii	Vein yellowing and outgrowths, enations.
	*Syringa vulgaris**	Yellow ring and line pattern, chevrons.
b) In field and hedgerow	*Fraxinus excelsior**	Yellow green lines.
	*Sambucus nigra**	Vein yellowing.

*virus-carrying nematodes detected in the root region of these plants.

In many instances high temperatures diminish and low temperatures accentuate symptoms. Thus, in autumn, field-grown AMV infected *F. americana* (on *F. excelsior* rootstocks) had distorted leaflets showing chlorotic ring or line patterns (Fig. 3) Yet in spring of the following year the commonest symptoms in these trees were puckering, twisting and chlorotic blotching (Fig. 4).

Symptoms alone cannot be used to identify an infecting virus although related viruses tend to produce similar types of symptoms. Thus leaf vein yellowing in elder (Fig. 5) has been shown to be caused experimentally by arabis mosaic (12) or tomato blackring virus or cherry leaf roll viruses (16).

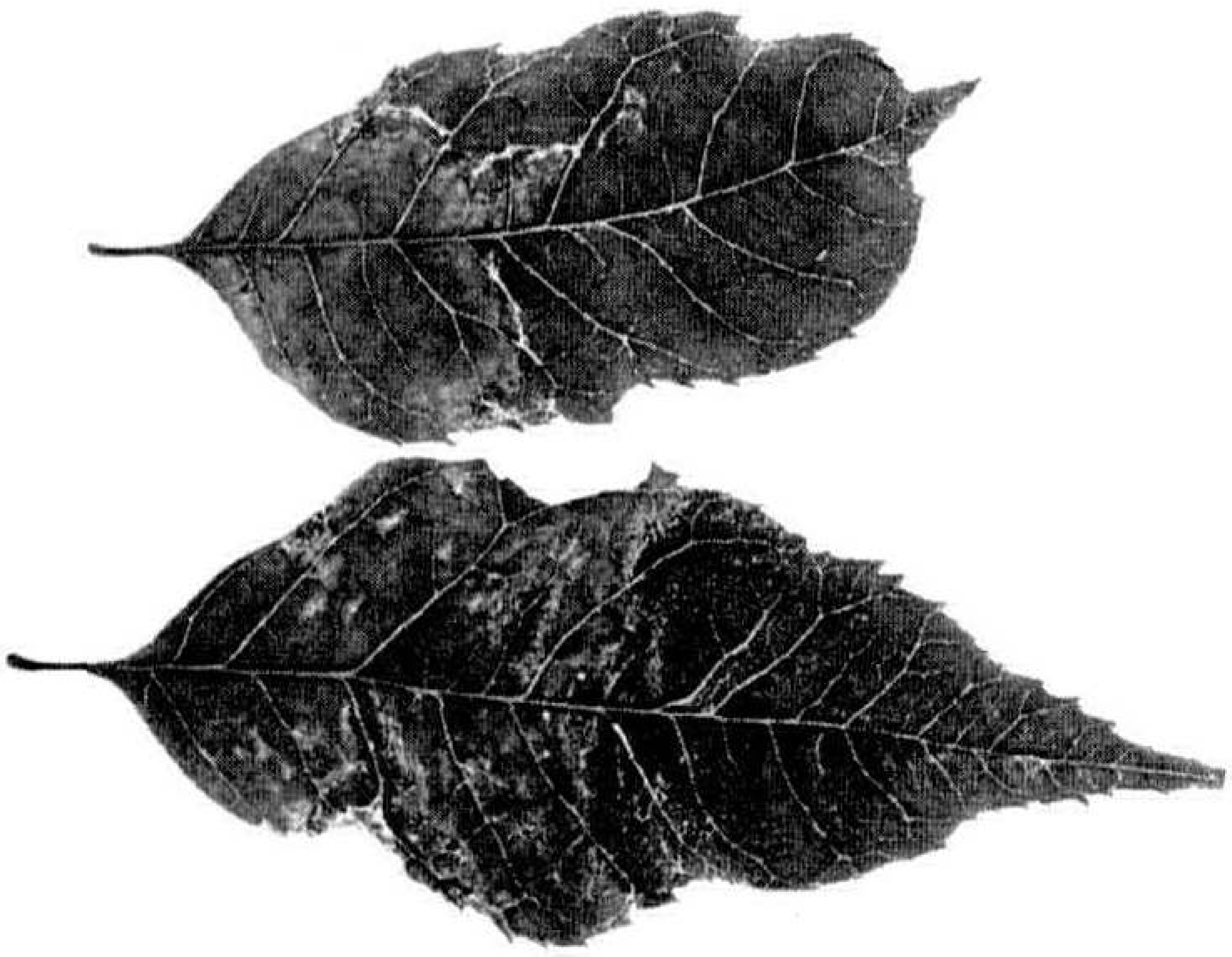

Figure 3. Leaflets of *Fraxinus americana* naturally infected with arabis mosaic virus and showing distortion with pale green line patterns in cool autumn weather.

Figure 4. Leaflets of *Fraxinus americana* naturally infected with arabis mosaic virus and showing puckering with pale green blotches in hot summer weather.

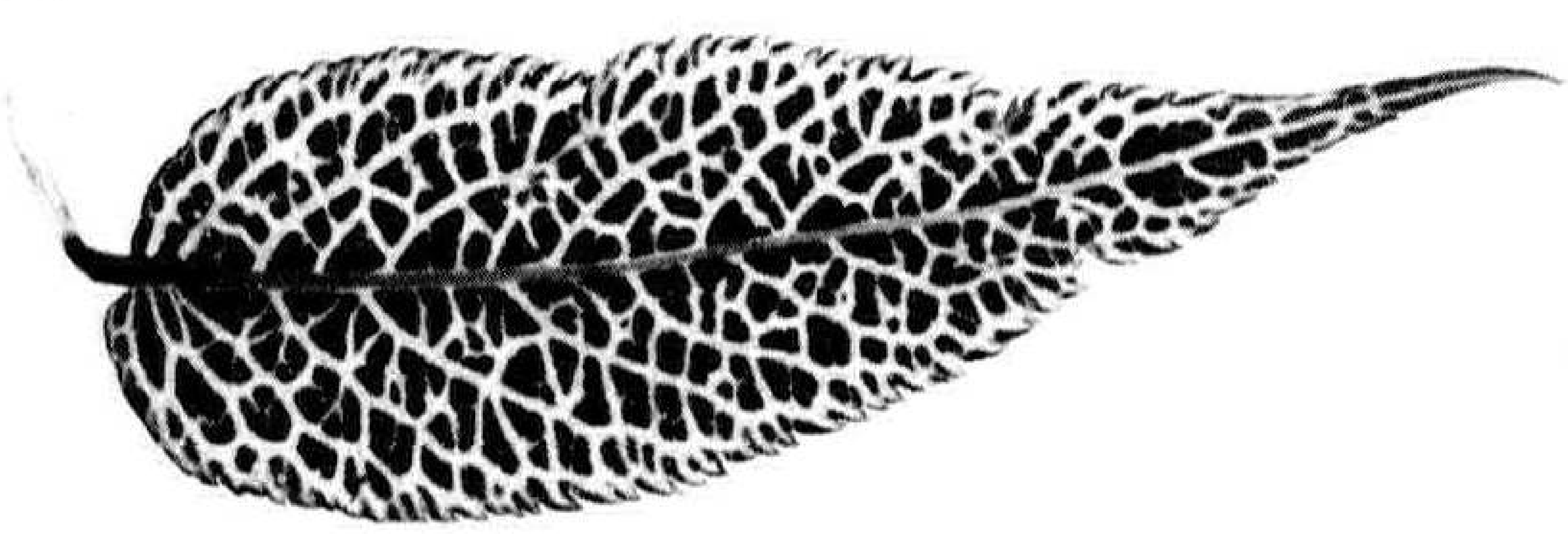

Figure 5. Leaflet of *Sambucus nigra* naturally infected with arabis mosaic virus and showing vein yellowing-yellow net.

Perennial plants are exposed to infection over several years and therefore are particularly liable to contain more than one virus simultaneously, e.g. ivy containing both AMV and SLRV showed symptoms indistinguishable from other ivy plants in which only AMV was found (Fig. 5). Consequently tests to confirm the pathogenicity of an infecting virus are signally appropriate to the study of viruses from trees and shrubs. Such tests are, however, infrequently done because of their long term nature. When confirming that AMV caused chlorotic line patterns in *F. excelsior* leaves, I found that only one of 18 ash seedlings (systemically infected after their cotyledons had been rubbed with purified and concentrated virus propagated in tobacco plants) showed symptoms in the first growing season although three additional plants produced similar, transient symptoms in the following year; 20 months after infection.

Figure 6. Leaf of *Hedera helix* naturally infected with arabis mosaic virus and showing yellow vein-banding patterns.

In addition to producing external symptoms, viruses also induce changes within the cells they infect. Observations made in Oxford on *Betula pendula* (*B. verrucosa*), naturally infected with CLRV, illustrate some of these. Birch leaves naturally infected with CLRV were first observed in Eastern Europe (18) and were more recently seen in Berkshire, Leicestershire, Lincolnshire and Oxfordshire (5). Symptoms tend to be most conspicuous in autumn when CLRV infected leaves typically show yellow ring and line patterns (Fig. 7).

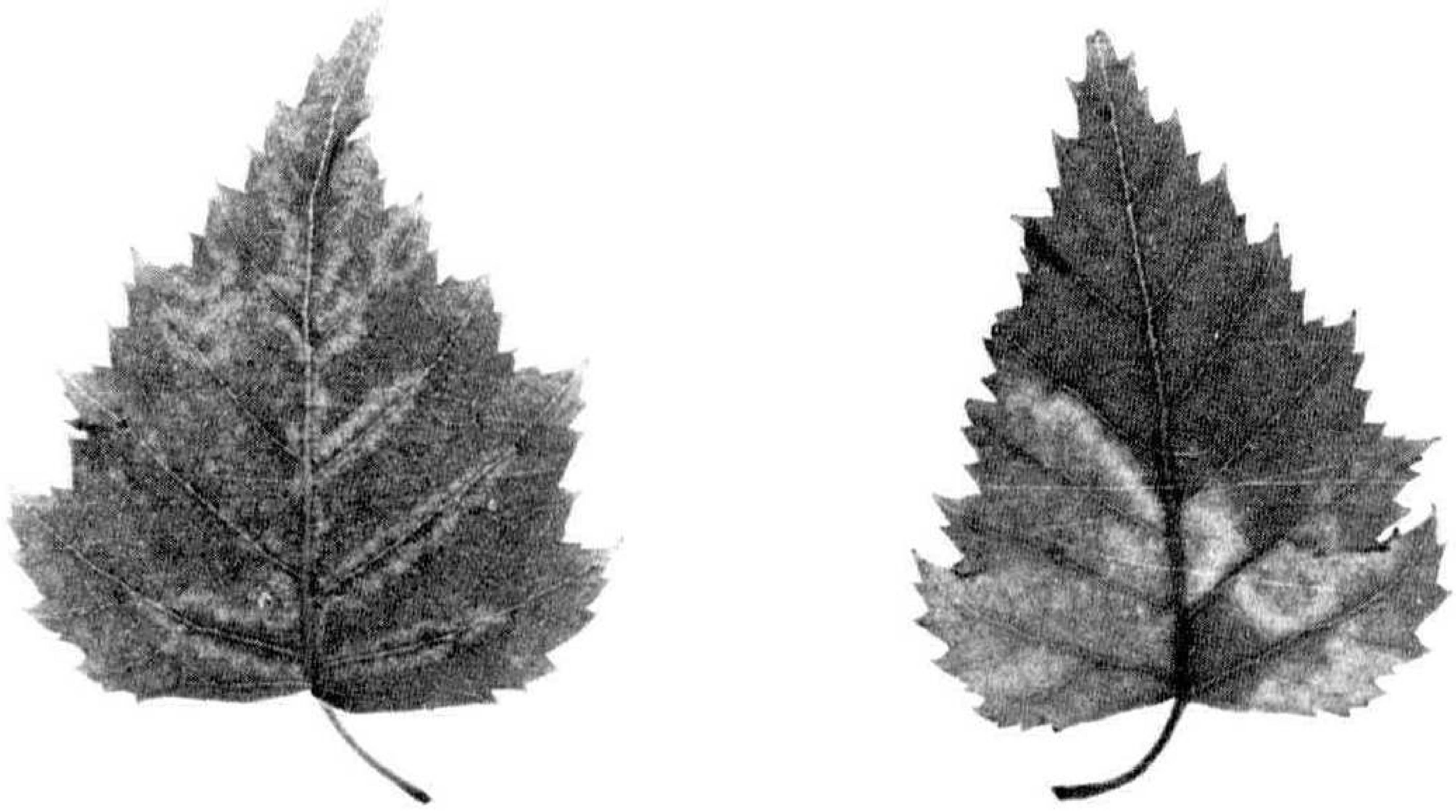

Figure 7. Leaves of *Betula pendula* naturally infected with cherry leaf roll virus and showing yellow vein banding and ring patterns.

Several differences were observed with the electron microscope in sections taken from naturally infected birch leaves in October when compared with tissues taken from symptomless and virus-free leaves collected on the same day from adjacent trees. Virus infected, unlike virus-free tissues, contained chloroplasts having many large black spots (densely stained plastoglobuli) and poorly defined lamellae. Furthermore, the cell well often intruded like fingers into the cytoplasm, the intrusions enclosing strings of virus-like particles. The deviations from normality shown by chloroplasts in virus-infected tissue were very likely to be harmful although it seems possible that cell wall overgrowth represents attempts by the host to prevent virus spreading from one cell to another.

THE SIGNIFICANCE OF VIRUS INFECTION

In woody perennials, a few viruses cause changes which have ornamental value (e.g. that which causes bright yellow mosaic patterns in leaves of *Abutilon*; Fig. 8). But the majority have effects which are only recognisable with difficulty. Despite this, knowledge from food crops indicates that viruses diminish growth rate although their significance may be apparent only when the productivity of virus-free plants having the same genetic constitution are available for comparison. It is difficult to draw general conclusions from the very few published data that describe the economic effects viruses have on the yield of woody plants but the following two examples give a guide. Top fruit and related ornamental rosaceous species have been generally found to grow more rapidly and crop better than virus-infected material (4) thereby justifying the EMLA scheme through which selected (usually fruiting) clones free of known viruses are offered to nurserymen to provide scions for grafting onto virus-free rootstocks. Some studies (1, 13, 14, 22) have also been made on the effects of poplar mosaic virus in poplar (Fig. 9) but different authors used different clones and none seem to have made sequential measurements over a period greater than four years. Collectively the data indicate that this virus causes losses in height and diameter growth which may be greater in some clones (e.g. *Populus* × *canadensis* (*P.* × *euramericana*) 'Eugenei', 15-20% than others (cv Gelrica, no significant effect). Marketable yield may also be affected by poplar mosaic virus which has been said to diminish the specific gravity and the strength of branch wood (1).

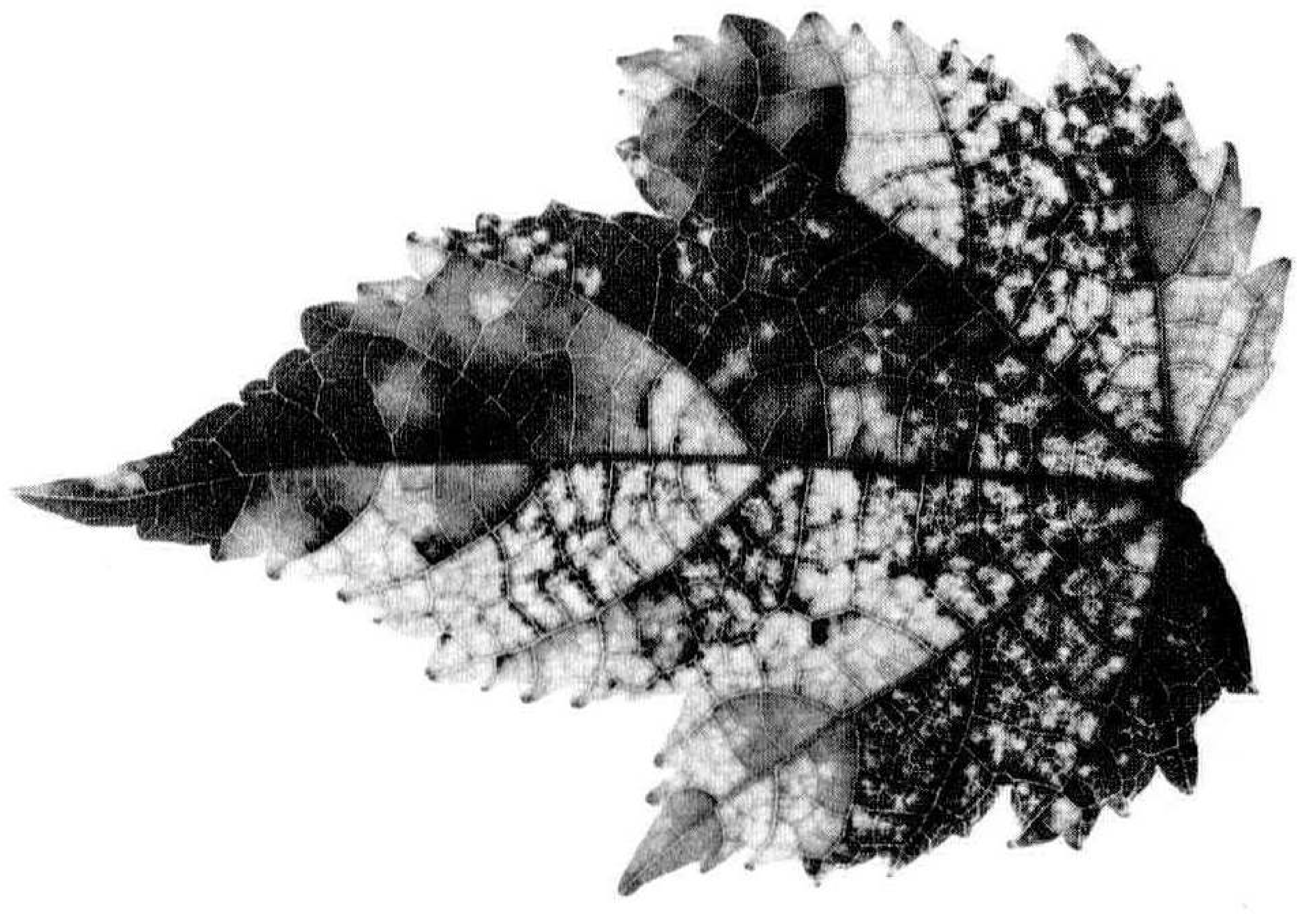

Figure 8. Leaf of *Abuliton* sp. showing the attractive bright yellow and green variegation caused by abutilon mosaic virus.

Figure 9. Leaves of *Populus* × *euramericana* naturally infected with poplar mosaic virus and showing yellow spots some of which extend along leaf veins — asteroid spotting.

WAYS TO IMPROVE THE HEALTH OF HARDY NURSERY STOCK

Uniformity of growth rate and extended production life are properties required by fruit growers and, by using existing techniques, it will be possible to obtain clones of virus-free trees and shrubs for timber or amenity planting. These clones would offer the nurserymen more evenness of stand that is now achieved but I doubt whether more uniform growth would by itself be adequate economic justification for the production of virus-free ornamental woody plant clones. The expense and effort may be justified when a virus is responsible for "incompatibility" (e.g. *Rosa rugosa* is a more or less symptomless carrier of strawberry latent ringspot virus until these plants are used as rootstocks for sensitive rose cultivars such as Peace or Superstar) or undesirable horticultural features which affect sales (e.g. virus associated decline of *Daphne mezereum*). The decision to develop virus free material must await more information about the incidence of viruses in hardy nursery stock and about the biology of the viruses themselves.

Alternative methods to prevent the dissemination of viruses are available; nurserymen should intensify their scrutiny of the plants they grow and discriminate against material that is in any way sub-standard or abnormal. Similarly, the risks from viruses will be minimised when healthy plants are isolated from sources of infection and virus-carrying vectors.

THE PROS AND CONS OF SEEDLING ROOTSTOCKS

A great many rootstocks used for hardy ornamentals are produced from seed. This is highly desirable because most viruses are not transmitted to a significant extent through seed, e.g. CLRV in birch about 2%. By contrast, vegetative propagation has a somewhat greater risk. Thus whereas most garden stocks of privet (over 90% in Oxford) are infected with AMV, relatively few (about 10% in Oxford) occur in soils infested with virus-carrying nematodes, thereby suggesting that the virus is likely to have been disseminated by vegetative propagation when seed, having by my estimate, approximately 1% risk of carrying the virus, could have been used.

The use of seedling rootstocks has somewhat broader phytosanitary implications. Most of the seedlings used in UK are imported *with roots attached* from Denmark. The Netherlands, or West Germany. Soil is inevitably introduced with rooted seedlings, thereby offering opportunities for the importation of non-indigenous soil-inhabiting pests and pathogens such as strains of the fungus *Syncytrium endobioticum* which can cause wart disease in potato cultivars immune to strains of the fungus present in UK. As far as is known, virus-vector nematodes occurring in the exporting countries also occur in UK. However, it is pertinent to point out that studies using nematode-transmitted viruses have shown that the reassortment of genetic material between two viruses present in one host can occur (10) and one cannot exclude the possibility that exotic virus strains may be introduced into UK in this way. Circumstantial evidence suggests that a free living nematode (*Paralongidorus maximus*) not known to be a virus vector but potentially damaging to woody plants on which it feeds, may have been introduced on seedling roots. *P. maximus* is known from Poland, Hungary, West Germany, Austria and France but although UK soils have been intensively examined (e.g. several thousand samples were studied by Dr. B. Boag at the Scottish Horticultural Research Institute) *P. maximus* was recorded three times only: in an ornamental nursery, a tree nursery and a private garden.

PROTECTION OF HARDY NURSERY STOCK FROM VIRUSES

Foliar applications with insecticidal chemicals may prevent the establishment of damaging insect populations but unfortunately viruses like cucumber and alfalfa mosaic are instantaneously transmitted when aphids feed and their spread is not greatly diminished either by systemically translocated or contact aphicides. Experiments with food crops have shown that plants can be protected from infection with viruses like cucumber mosaic. Mineral oil emulsions could be sprayed onto leaves, reflecting (aluminum foil), mulches could be applied around plants and a tall growing barrier crop such as rye could be established around stock to be protected. The prospects for controlling the spread of nematode-borne viruses by changes in management or soil treatment are, however, more encouraging.

Nematode-borne viruses will be avoided by growing plants in containers, but only if the compost is sterilized; all the virus-carrying genera naturally infest a wide range of soils and *Xiphinema diversicaudatum* has been reported from sphagnum peat used for potting compost in The Netherlands (19). Several chemicals when applied to soil have been shown to kill nematodes and to prevent the spread of viruses they carry (6, 11, 15). New techniques may need to be developed to achieve adequate nematicidal effect at great depths in soil permeated by roots of large trees but there is considerable knowledge available concerning the use of nematicides to protect shallow rooted annual and perennial crops and this will be relevant to hardy nursery stock problems. The cost of soil treatment is high but nematodes (including those carrying viruses) cause root damage when feeding and have, in many instances, been detected in tree nursery sites (6, 21) or in the root regions of mature trees (2, 12).

Indeed, one reason why AMV is frequent in hardy nursery stock is that although X. *diversicaudatum* feeds on roots of many plants, the nematodes multiply relatively more on woody perennial rather than weed or herbaceous crop plants (20). Large numbers of virus-carrying nematodes are often associated with hedgerows which may also contain virus-infected trees, therefore areas cleared from hedgerows should be set to arable rotations which tend to discourage X. *diversicaudatum* and wide fallow headlands should be left when practical because nematodes move laterally in soil, albeit slowly.

CONCLUSIONS

The frequency with which viruses have been detected in the few speculative and opportunist tests recently made on ornamental woody shrubs and trees suggests that a programme of virus-testing horticultural clones of the more widely grown plants (to select healthy stocks) might be desirable. Nurserymen should take particular care when selecting material for propagation because man has played an important part in spreading viruses. Graft transmission of a disease is not an adequate proof that a virus is the cause; characterization of a virus and tests to show its pathogenicity are needed. A more intensified research effort also seems justified to assess (a) the effects of viruses on the growth and propagation of hardy nursery stock; (b) the risk that trees and shrubs may pose as sources of viruses transmissible to and perhaps more damaging in neighbouring food crops.

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