Proc. 6th Br. Insectic. Fungic. Conf. (1971)

THE SPREAD AND CONTROL OF NETTLEHEAD AND OTHER DISEASES OF HOP ASSOCIATED WITH ARABIS MOSAIC VIRUS

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Summary Nettlehead, severe split leaf blotch and bare bine are serious and prevalent diseases of English hops that are associated with the presence of an unusual strain of arabis mosaic virus. This is disseminated in many of the stocks being raised within the main hop-growing areas and is transmitted by the dagger nematode (*Xiphinema diversicaudatum*).

The hop is not a good host of the nematode and many areas are not infested or support only low scattered populations. This suggests that the present high level of virus infection is due more to the use of infected stock than to spread by nematodes.

Present losses can be decreased by selecting sites free from dagger nematode for all new plantings and by the increased use of virus-tested planting material. Fumigation and fallowing are being tried for use at the relatively few sites with a consistently high population of infective nematodes.

INTRODUCTION

There are approximately 17,000 acres (6,900 ha) of hops in England producing an annual crop of 10,000 tons (10,160 tonnes) worth £7-8 million to the 550 or so growers involved. Yields and profitability are seriously affected by pests and fungus diseases. However, there has been no estimate of the losses caused by virus diseases, although some of these have long been known to be widespread, severe and prevalent. Nettlehead disease was first described in 1574 and hop mosaic and split leaf blotch have been studied for almost 50 years.

Progress in the control of the principal virus diseases has been impeded by inadequate information on their etiology and on the identity of their vectors. This situation was transformed by the discovery of an unusual strain of arabis mosaic virus (AMV) in hop (Bock, 1966) that is transmitted by the dagger nematode (*Xiphinema diversicaudatum*) and associated with nettlehead and split leaf blotch diseases and also with the 'bare bine' condition. This paper summarises present information on these diseases and on their control.

Nettlehead and other diseases associated with arabis mosaic virus

The strain of AMV occurring in hop differs from those isolated from other crop plants in that it seldom causes symptoms in herbaceous indicator plants. Any symptoms that do develop are slight, slow to appear and often preceded or obscured by those of prunus necrotic ringspot virus, which is present in all commercial clones of English hops. A serological technique provides an alternative method of detecting AMV in the sap squeezed from young hop leaves or shoots. This method is quick, gives reliable results and has been used extensively to assess the incidence of AMV in commercial plantings.

The first association of AMV with nettlehead disease (Bock, 1966) has been confirmed by all subsequent tests on material of different varieties from widely separated areas in the West Midlands and in the south east. Nettlehead is common in both regions and must cause substantial losses as affected plants are severely stunted and produce little crop (Legg, 1959). Symptoms are most obvious in early summer, when affected leaves develop a mottle or vein clearing, with enations growing from the undersides of the mid-rib and main veins. Leaves are rolled upwards and the shoots fail to climb so that they fall away from the supporting strings (Keyworth and Davies, 1946).

AMV is present in all hops with nettlehead disease, but the virus also occurs in many other hops and sites where nettlehead has never been reported. In the widely grown variety 'Fuggle', infection is always associated with severe split leaf blotch disease (Keyworth, 1951), which seems to predispose plants to nettlehead and often precedes it (Legg and Ormerod, 1964). Severe blotch alone decreases growth and crop; in aggregate it causes greater losses than nettlehead, which although more damaging, is much less prevalent (Legg, 1959).

When growth commences in the spring, 'Fuggle' plants that will later develop severe blotch have a weak unthrifty appearance. Unusually few shoots develop and these have a characteristic curvature, dark pigmentation and leaves that are few, small and retarded (Keyworth, 1951). This transient 'bare bine' condition is just as widespread in other varieties as severe blotch in 'Fuggles' and there is a similar association with AMV, but no blotch. Bare bine in these varieties may be followed by nettlehead but most plants recover and become symptomless until the following spring. Nevertheless their yield is diminished (Neve and Thompson, unpublished) and the aggregate effect on crop is likely to be substantial.

The transmission of nettlehead and the hop strain of AMV by dagger nematodes

Nettlehead disease often recurs and spreads slowly at the same site in successive crops; it tends to be particularly prevalent alongside hedgerows, where hedges have been grubbed and when hops follow permanent pasture or orchards (Keyworth and Hitchcock, 1948). These features suggest that infection is soil-borne, but early attempts to confirm this were unsuccessful. Moreover, inoculations to herbaceous hosts failed to detect AMV or any of the other nematode-transmitted viruses (Legg, 1964a) and the first hop soils examined contained few nematodes of known vector species.

The situation was transformed by the recovery of substantial numbers of dagger nematodes from soils where nettlehead was spreading and by the ability to detect the hop strain of AMV (Bock, 1966). This prompted transmission experiments with hand-picked dagger nematodes, which were done concurrently with those of R.B. Valdez, in our laboratory. High rates of transmission of AMV have been obtained between hops. Nettlehead was also transmitted to hop seedlings by nematodes obtained from the soil around infected plants in the field or in the glasshouse. These results emphasize the importance of dagger nematodes in hop soils and are consistent with traditional observations because the nematode can persist in fallow soil and spreads slowly amongst its host plants. Moreover, the species is numerous in hedgerow soils and often occurs in smaller numbers in permanent pasture or orchard land, but seldom where arable crops are grown.

Control

The total losses caused by nettlehead and the other diseases associated with AMV cannot be assessed on present evidence, although they are likely to be considerable as the productivity of many plantings is seriously diminished. Some become totally uneconomic and have to be replaced prematurely, while other sites have to be abandoned and new ones found, with the additional expense of erecting costly wirework and supporting poles. The information now available allows a more rational approach to control measures than hitherto and is of great significance to growers.

Planting material

Growers have long been urged to plant 'A plus' Ministry-certified sets raised from specially selected stocks in isolated areas (Legg, 1964b). The original justification for this advice was the lower incidence of nettlehead in plantings made with 'A plus' material compared with those of unselected 'A' and uncertified stocks propagated within the hop-growing areas (Legg, 1964a and unpublished). Despite this there has been only a limited demand for 'A plus' sets and two-thirds of all recent plantings comprised unselected material (Thresh and Ormerod, 1971).

The superior performance of 'A plus' plantings is explained by their initial freedom from AMV, which is now known to be common in many of the unselected commercial stocks. This emphasizes the importance of the original advice. The use of carefully selected material for all new plantings will avoid introducing virus to hitherto non-infective populations of dagger nematodes and will decrease the present widespread occurrence of infection at sites free from the nematode.

Site

Growers can now be more discriminating than previously in selecting sites least likely to be affected by nettlehead and related diseases. Increasing use is already being made of the facilities of the Agricultural Development and Advisory Service for sampling soils to assay nematode populations. Unfortunately there is no convenient way of testing their infectivity and there are limits to the number of routine samples that can be collected and processed. There are also problems in developing a reliable sampling procedure for an organism so patchily distributed in the huge volumes of top-soil involved.

Despite these limitations it is usually possible to locate the relatively few sites where dagger nematodes are widespread and numerous. Hop growing should cease on such sites with a previous history of virus disease, unless an effective fumigation or other preplanting technique can be developed. Sites with dagger nematodes but no previous history of hop cultivation should also be avoided wherever possible, pending further information on the precise risks involved to a subsequent crop of hops. On no account should they be planted with inferior material.

Present indications are that hop is not a good host of dagger nematodes, that consistently high populations of the nematode are restricted to relatively few sites and that many areas are infested or support only low, scattered populations. Growers do not seem to have been seriously inconvenienced by the need to find nematode-free land for new plantings and usually they have been able to offer an alternative area should one be rejected. Indeed, the present high level of infection seems to be due more to the continued use of inferior planting material than to spread by infective nematodes.

Fallowing and crop rotation

Fallowing and crop rotation offer only limited prospects of eliminating dagger nematodes from hop soils because the nematode can feed and reproduce on the roots of many crop and weed hosts and can survive long periods in bare soil. Nevertheless, virus does not persist through the larval moults and the long-lived adults may not retain virus indefinitely. A replicated trial at Headcorn, Kent, has indicated that their infectivity declines sharply in the second year of bare fallowing of nettlehead land. Similar trends have been apparent from observations elsewhere and it is the standard practice of some growers to fallow for two seasons before replanting. This is not always possible when hops are in great demand and the immediate replanting of many infected sites in 1968-1969 and 1969-1970 gave the maximum opportunity for infective nematodes to survive (Thresh and Ormerod, 1971).

Fumigation

Growers may be particularly anxious to retain the wirework and continue hop production in certain areas despite the likelihood of nettlehead recurring. In these circumstances fumigation to control nematodes offers a possible solution, even though it may be expensive and require special soil preparation.

Satisfactory control will be especially difficult to achieve in the hop, which is a deep-rooted perennial, often grown in very heavy clays. Dagger nematodes may occur to a depth of 3 ft (0.9 m) and a mean population of only one individual per 200 ml soil sample is equivalent to about 12,000 around a single hop root system.

Despite these difficulties, some success has been achieved in a series of field trials. Methyl bromide applied at 480 lb/ac (540 kg/ha) at Headcorn, Kent, under suboptimal soil conditions in the late spring of 1967, failed to control virus or vector and replanted 'Fuggle' hops were severely affected by blotch and nettlehead within three years. By contrast, an autumn application of a mixture of dichloropropene and dichloropropane (DD) by hand injection, at the rate of 25 gal/ac (282 l/ha), effectively controlled nematodes in some plots and halved the overall incidence of nettlehead and AMV in the second growing season compared with untreated controls. A similar application at the rate of 50 gal/ac (563 l/ha) in 1968 was even more effective and the population occurring down to 24in(0.6 m) was only 2% of that in untreated plots.

The original trials and the first results of later ones have justified further experiments involving the injection of much larger areas by tractor-drawn machines. Adaptations of the Auchincruive and Leaper-Ramsay machines developed for injecting potato and sugar beet land, respectively, and also a Danish machine designed for use in tree nurseries have been used in trials. All three machines have also been used recently by growers in attempts at commercial control.

Future prospects

Present measures are intended primarily to avoid disease. There is no practical method of curing infected plants in the field and no evidence of immunity or of a level of resistance or tolerance to virus or vector that could be exploited by plant breeding. The advice that can be offered to growers to avoid the recurrence of infection at sites with an extensive infestation of infective nematodes is limited at present but current studies on fallowing and fumigation offer some prospect of success. However, as the present chemicals are phytotoxic and can be