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FALLOWING AND FUMIGATION EXPERIMENTS ON THE CONTROL OF NETTLEHEAD AND RELATED VIRUS DISEASES OF HOP

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Summary In a series of field experiments in hop plantations, fallowing and soil fumigation were compared in attempts to control nettlehead and related diseases associated with infection by arabis mosaic virus, which is transmitted by the dagger nematode *Xiphinema diversicaudatum*.

Although several years of bare fallow had little effect on populations of the vector compared to the high mortality caused by injecting soils with a mixture of dichloropropene and dichloropropane (D-D), fallowing was as effective as fumigation in preventing the infection of hops planted after 21 months. In other trials infection was prevented entirely after a 2-year bare fallow or by growing crops of strawberry or rye grass for 3 years.

Possible control measures are discussed, especially for the benefit of growers anxious to replant severely affected sites, with a minimum of delay, using the new high-yielding varieties.

Une série d'essais dans des houblonnières a comparé la mise en jachère avec la fumigation du sol pour lutter contre le nettlehead ("tête d' ortie") et les maladies semblables. Ces maladies proviennent de l'infection par le virus de la mosaïque de l'arabette (arabis mosaic virus) transmis par le nématode *Xiphinema diversicaudatum*.

La mise en jachère pendant plusieurs années a eu peu d'effet sur la population de nématodes par comparaison à l'injection au sol d'un mélange de dichloropropene et de dichloropropane (D-D), qui a entraîné une forte mortalité. Cependant la jachère s'est révélée aussi efficace que la fumigation pour empêcher l'infection par le virus de houblon planté après 21 mois de jachère. Dans d'autres essais l'infection a été empêchée complètement après un traitement comprenant ou une jachère nue pendant deux ans ou la culture de fraisiers ou de ray-grass pendant trois ans.

Les mesures de lutte à employer sont discutées, surtout par rapport aux houblonniers qui veulent replanter le plus rapidement possible leurs houblonnières infestées avec les nouvelles variétés de houblon à haut rendement.

INTRODUCTION

Nettlehead and split leaf blotch diseases of the hop (Humulus lupulus) are caused by widespread and prevalent viruses. Growers have long been advised to plant Ministry-certified 'A plus' stocks of the best available health status (Legg, 1964). However, specific control measures could not be recommended because of the limited information available on the etiology of the diseases and their mode of spread.

The situation changed when nettlehead and severe split leaf blotch diseases and the even more widespread condition known as bare bine were associated with infection by an unusual strain of arabis mosaic virus (Bock, 1966; Thresh and Pitcher, 1971). Growers can now be much more discriminating in selecting sites and planting material. In addition field experiments were started on fallowing and fumigation regimes on severely affected sites. The preliminary results now presented indicate the excellent prospects for decreasing reinfection by fallowing prior to replanting,especially when combined with the use of a nematicide.

MATERIALS AND METHODS

The main fallowing/fumigation experiment was carried out at a site near Headcorn, Kent, where nettlehead has long been prevalent and the dagger nematode Xiphinema diversicaudatum was present at a mean population of 18.5 per 200 ml soil. The area was cleared of hops in March 1968 and divided equally into six main plots. Three were selected at random and treated with D-D in early October 1968 at the rate of 560 l/ha. The fumigant was applied by hand injector gun at a depth of 15 cm after deep ploughing and repeated cultivations.

One fifth of each plot was replanted in late October, 1968 and similar sub-plots were replanted in the four succeeding years. Each of the six-sub-plots consisted of a 5 x 3 array of 15 plants at a regular square spacing of 1.8 m x 1.8 m. The three untreated plots were subdivided and planted in a similar way.

Weed control received particular attention throughout the experiment. A paraquat/simazine regime was used successfully, except in the summer of 1968, when many hop seedlings developed. Initially there was also much regeneration from the hop shoots, runners and other remaining pieces of stem which were dug out or killed by spot applications of aminotriazole.

Soil fumigation with D-D was tried elsewhere in Kent and at the ADAS Rosemaund Experimental Husbandry Farm, Hereford, where split leaf blotch disease was locally severe. In other experiments, still in progress, D-D was applied by one of three types of tractor-drawn machine. These were the Achincruive, Leaper-Ramsay and Egedal injectors, designed originally for treating potato, sugar beet and nursery soils, respectively. The Leaper-Ramsay machine was the easiest to use as the jets were least likely to become blocked and the fumigant was delivered at a constant pressure in a way that made it easy to measure and standardise the volume applied.

All sites were replanted with certified rooted cuttings raised in East Anglia and free initially from arabis mosaic virus (AMV). The incidence of this virus was assessed annually each April or May. It was convenient to use a serological test and, except after long periods of very hot weather, drops of leaf sap containing AMV formed clear specific lines in agar gels on reacting with suitable dilutions of antiserum.

Nematode numbers were estimated following extraction by a modification of Cobb's decanting and sieving method (Flegg, 1967) from soil samples taken at a depth of 15-30 cm.

RESULTS

Untreated Headcorn plots

Dagger nematode populations Populations remained high in the untreated plots for 19 months after grubbing (mean 21.0 per 200 ml soil). Thereafter there was a slow decline in the numbers detected to a mean of 10.0 after 54 months. Populations were very variable but did not differ markedly between plots replanted with hops and those still in bare fallow, even after almost 5 years. This result was unexpected considering the excellent weed control achieved throughout the trial, after the first year, which deprived the nematodes of any alternative host plants.

Virus infection AMV was not detected in the shoots of any of the replants during their first year of growth and none developed symptoms. However 11% of the plants had become infected with AMV by the second year in sub-plots planted after the minimum fallow period of 8 months and the rate of infection increased to 67% in succeeding years. Many of the AMV-infected plants developed symptoms of nettlehead disease, whereas all the AMV-free plants remained symptomless. No plants contracted AMV in sub-plots replanted after bare-fallow periods of 21 months or longer, despite the fact that the nematode populations had not fallen appreciably. These data indicate the striking effect of prolonged bare fallow in decreasing the infectivity of dagger nematodes surviving in the soil.

D-D treated Headcorn plots

Dagger nematode populations Pre-treatment samples had revealed similar numbers of dagger nematodes in the untreated plots and those later fumigated with D-D (mean 18.5 per 200 ml). After treatment, dagger nematodes occurred in samples from only six of the fifteen fumigated sub-plots (overall mean 0.3 per 200 ml).

For 3 years the populations remained low but one of the fallowed plots sampled after 45 and 74 months yielded 20 and 74 nematodes per 200 ml of soil, respectively (means 1.5 and 6.1). There was clear evidence of nematode breeding along one edge of this plot and to a lesser extent in neighbouring plots. All adjoined a 4 m-wide grass headland bordered by a hedgerow of woody perennials whose roots had invaded the margins of the experimental plots.

Virus infection The high mortality of the vector nematodes caused by D-D treatment was associated with a decreased incidence of

AMV and nettlehead compared with the untreated plots. The 11% AMV-infection recorded after 5 years in the sub-plots replanted after 8 months represented 83% control. As in the untreated areas, no AMV infection occurred in sub-plots treated and replanted after fallow periods of 21 months or longer, indicating that the few nematode survivors of D-D had also lost their infectivity.

Results from other sites

The results obtained at other sites are consistent with those obtained at Headcorn. Invariably, much reinfection with AMV occurred within 2 years when sites with a previous history of nettlehead and/or severe split leaf blotch were replanted immediately or within a few months of removing the previous crop. Near Horsmonden, for example, there was 64% infection in plots replanted immediately, compared with only 7% infection in adjacent untreated plots replanted after a 1-year fallow. There was no infection in comparable plots treated with D-D at 840 l/ha using the Egedal injector. Elsewhere there has been little reinfection on replanting after a 1-year fallow and even less in comparable D-D treated plots.

It is necessary or desirable to leave land unplanted for at least one growing season to ensure adequate preparation of the soil for injection. The low level of reinfection encountered in such circumstances, even in untreated plots, has made it difficult to compare the effects on AMV of different rates, placement and methods of injecting D-D.

At the Rosemaund site a hop planting that was severely affected by split leaf blotch was grubbed and replanted with healthy stocks after 3 years. Throughout the intervening period some plots were kept bare by herbicides and others planted with hop, strawberry or perennial rye grass. Populations of dagger nematodes increased under strawberry and rye grass but were little changed in the bare fallow and hop areas. Nevertheless, there was no infection in the strawberry, grass or bare fallow plots within 2 years of grubbing and replanting the whole area with hops. However, reinfection was almost total in plots in which hop plants had been grown, despite the relatively low nematode populations (mean of 5.0 per 200 ml soil).

DISCUSSION

Various nematicides have been used by other workers in Britain and elsewhere to treat soils containing populations of virus infective nematodes. D-D has been effective in preventing the subsequent re-infection of crops of strawberry and raspberry by viruses of the nepo group (Taylor & Gordon, 1970). It has been much more difficult to prevent the reinfection of longer-lived and deeper-rooted crops such as grapevine. The most successful measures against grape fanleaf and related viruses transmitted by *Xiphinema index* have involved double applications of high rates of D-D applied to a depth up to about 1 m by very heavy machinery after special preparation of light sandy soils. (Raski & Schmidt, 1972).

Considerable difficulties have also been encountered in treating hop soils, which tend to be very heavy and difficult to cultivate adequately to the required depth. Problems are also caused by uncertain weather and for much of the year soil conditions do not permit effective treatment. Moreover, hop roots exploit a very large volume of soil and one nematode per 200 ml soil sample is equivalent to approximately 12,000 around the roots of one mature hop plant. Even a treatment that causes 99% mortality leaves many potential vectors unharmed.

Thus it is not surprising that the fumigation of hop soils has given somewhat disappointing results. It is at present impossible to recommend a chemical treatment that will allow the immediate replanting of a severely affected site without serious risk of reinfection. Some control may be achieved under favourable circumstances, but it is doubtful whether the effect is sufficiently great to justify the expense unless there is an interval of at least 1 year between grubbing and replanting with healthy stock. The year out of hop required for preparing the soil for fumigation results in a drastic decrease in the infectivity of those nematodes that survive the necessary cultivations.

The marked effectiveness of a prolonged fallow period in preventing reinfection was totally unexpected at the outset, yet in all experiments and all other observed sites the amount of reinfection decreased with increasing interval between plantings. This was not accompanied by a corresponding decrease in the nematode populations and must therefore have been due to their failure to transmit. This view is supported by laboratory studies (Valdez et al., 1973), indicating that dagger nematodes may lose their infectivity with AMV after 36 weeks starvation.

The substantial control of nettlehead achieved by 1-year fallow must have been one of several advantages which led empirically to the adoption of this traditional hop-growing practice. Unfortunately, 1 year of bare fallow is not completely effective and growers are reluctant to adopt longer periods because of the loss of revenue and because weed control is now more easily achieved by the use of herbicides. There is a special incentive at present to replant at the earliest possible opportunity, using the new high-yielding varieties and to meet the demand for hops with a high content of alpha-acid. In these circumstances some growers are fumigating severely affected sites with D-D or dichloropropene during the year out of hops. Alternatively, they are advised to grub in the autumn immediately after harvest and replant untreated land with mist-propagated cuttings 21 months later; so losing only one full crop. Longer periods of fallow would be more acceptable to growers if alternative crops could be recommended. This emphasises the importance of the latest results, in which strawberries or a grass ley grown for 3 years were as effective as bare fallow in preventing the infection of a subsequent hop planting. For all replanting it is essential to use 'A plus' certified stock and so avoid reintroducing AMV to the surviving nematodes, which would then be able to resume transmission.

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