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# BARLEY MILDEW FORECASTING

R.W. Polley
M.A.F.F. Plant Pathology Laboratory, Harpenden, Hertfordshire.
L.P. Smith
Meteorological Office, London Road, Bracknell, Berkshire.

Summary Two forecasting methods for barley mildew based on meteorological data are described one initially designed to predict high mildew spore counts, and the second to detect the date on which a foliar spray would be likely to give the best grain yield. When applied to the results of A.D.A.S. spray-timing trials and spore trapping work carried out in 1972, it was found that the first method accurately predicted the majority of spore peaks and both methods successfully predicted over 50% of the best spray dates to within one week.

Résumé Deux méthodes de prévision pour la moissisure d'orge basées sur des données météorologiques sont décrites; l'une destinée à prédire les numérations élevés des spores de moissisure et l'autre à trouver la date quand une pulvérisation foliaire était probable à donner la meilleure récolte des graines. Quand ces deux méthodes étaient appliquées aux résultats des essais destinés à régler la fréquence de la pulvérisation et à attraper des spores effectués par l'A.D.A.S (service de consultation et de developpement agricole) en 1972 on a trouvé que la première méthode prédisait très exactement la plupart des apogées des spores et les deux méthodes prédisaient correctement plus que 50% des meilleures dates pour la pulvérisation à une semaine près.

## INTRODUCTION

Powdery mildew (Erysiphe graminis) of barley has been estimated to be a very destructive disease in Britain (King, 1972) and many growers acknowledge this by their willingness to use commercially available mildewicides either as seed dressings or foliar sprays to control the disease. Since economically it is feasible to use only a single spray on most crops, a scheme to determine the optimum time for the application of the spray in terms of mildew control and increase of grain yield is desirable in order to obtain maximum economic return from such control measures.

Polley and King (1973) showed that days on which large numbers of mildew conidia were caught on spore traps above the crop generally coincided with periods when there was a high incidence of infection followed by subsequent disease development in the crop. They suggested that the following criteria were favourable for spore release from infected plants and could be used for forecasting high spore numbers:-

1) Day max. temp. above 15.6$^0$C
2) Day sunshine more than 5 h
3) Day rainfall less than 1 mm
4) Run-of-wind above 246 km per 24 h.

Smith and Davies (1973) produced evidence that wind strength and temperature affected the spore catch, and Smith (unpublished) devised a method for predicting the optimum spray date from results of A.D.A.S. spray timing trials in 1971 and 1972. This method involved the calculation of an index equal to $3T+\frac{1}{2}W+H$ where T=day maximum temperature in $^0$C, W=wind speed in knots at 1200 h and H=hours of sunshine. Critical days occurred when the value of this index exceeded 64.

The purpose of this paper is to discuss the performance of these forecasting proposals when applied to the results of A.D.A.S. spray timing trials and spore trapping work carried out in 1972.

## METHOD AND MATERIALS

The following rules were applied to the two sets of criteria described above in order to define critical periods:-

1) Polley and King criteria:-

i) A high risk day is one on which all four factors (see I.troduction) have been satisfied, <u>or</u> the second consecutive day when three-quarters of the factors have been satisfied, <u>or</u> the third consecutive day on which at least two factors have been satisfied with one or two of those days having had three satisfied.

ii) A high risk day will denote the start of a critical period which is terminated by a day when zero or one factor has been satisfied or the third consecutive day when only two factors have been satisfied.

iii) At least six clear days must elapse between the start of consecutive periods to allow for incubation. If conditions are continuous for seven days or more, a second period commences seven days after the start of the first.

2) Smith criteria:-

Starting from the day when mildew is first reported to be present in the crop, the forecast best spray date in terms of grain yield is the second day or days with an index value greater than 64 separated by at least five days from the first.

The Polley and King criteria were originally devised for forecasting spore peaks and were tested by placing sticky cylinder spore traps, developed at Rothamsted Experimental Station, in barley crops at several sites distributed throughout the country. Each trap consisted of a piece of gelatin-coated cellophane 25 mm wide, wrapped once round a 4.8 mm diam. brass rod and held beneath a perspex rain-guard. The traps were raised at intervals to keep them a few cm above the top of the crop. The rods were changed at 1700 h each day throughout May and June. Following exposure of the trap, the cellophane was peeled from the rod and mounted on a glass slide. Spores on ten traverses of the sticky surface were counted, each traverse being 500 $\mu$m wide, and the spore counts were expressed as the number trapped per sq cm of sticky surface per day.

Results from A.D.A.S. spray timing trials in 1972 were used to assess the performance of the two forecasting schemes in relation to grain yields.

## RESULTS

Daily spore counts are shown in Fig.1 together with the critical periods based on the Polley and King criteria.

The weather throughout May and most of June in 1972 was notably cool and changeable resulting in a slow build up of mildew. However, at sites in eastern and southern England, spore trap counts were high at the end of May and this was probably associated with the high wind speeds which occurred during the second half of the month. A brief spell of warm weather in mid-June coincided with the production of large numbers of spores at all the sites and was probably responsible for the general build-up of the disease in many northern and western areas. Crops in these areas tended to mature later than those in the south and east, and during mid-June were at a more susceptible growth stage. This is reflected in the results of the 1972 A.D.A.S barley foliar disease survey (King 1973) which showed that mildew levels at growth stage 11.1 were higher in the north and west than in the east and south where rapid development of the epidemic commenced somewhat earlier, within two weeks of the high spore counts at the end of May.

Predicted high spore counts based on the Polley and King criteria generally achieved a reasonable degree of accuracy. When used to forecast optimum spray dates it was found that, for crops adjacent to winter barley, the 2nd or 3rd critical period after the beginning of May was the operative one, whilst for crops in other situations, the 4th period was operative. A forecast on this basis would have predicted to within one week 56% of the spray dates which gave the highest grain yield increases in A.D.A.S. spray timing trials in 1972. A similar comparison using the Smith index showed that the criteria predicted 64% of the best spray dates. Examination of the resultant yields in these trials indicate that on no occasion would the yield obtained by spraying on the forecast dates be less than 92% of the yield obtained after spraying on the best single date, and on average the yields were 97.5% of the 'best date' yields which themselves resulted in an average 13% increase in yield over unsprayed plots. The detailed results of these trials will be published elsewhere.

## DISCUSSION

The degree of success attained by the two forecasting schemes in 1972 indicates that weather conditions were affecting mildew development sufficiently to enable fairly accurate predictions to be made. Relatively high temperatures and wind speeds are probably conducive to spore production and dispersal respectively. The role of rainfall is difficult to assess and may well be twofold. Water stress in the plants during dry periods may reduce the susceptibility of the plants to mildew due to suppression of the plants' metabolism. Moderate to heavy rainfall, however, damages conidiophores, and recovery of the fungus can take up to three days (Hirst 1953, Sreeramulu 1964). Other factors such as nutrition (Last 1962) sowing date (Last 1957) and variety also affect the susceptibility of the crop, and any barley mildew forecasting scheme must take these into account. Thus,

Fig.1. Barley mildew spore trapping results 1972

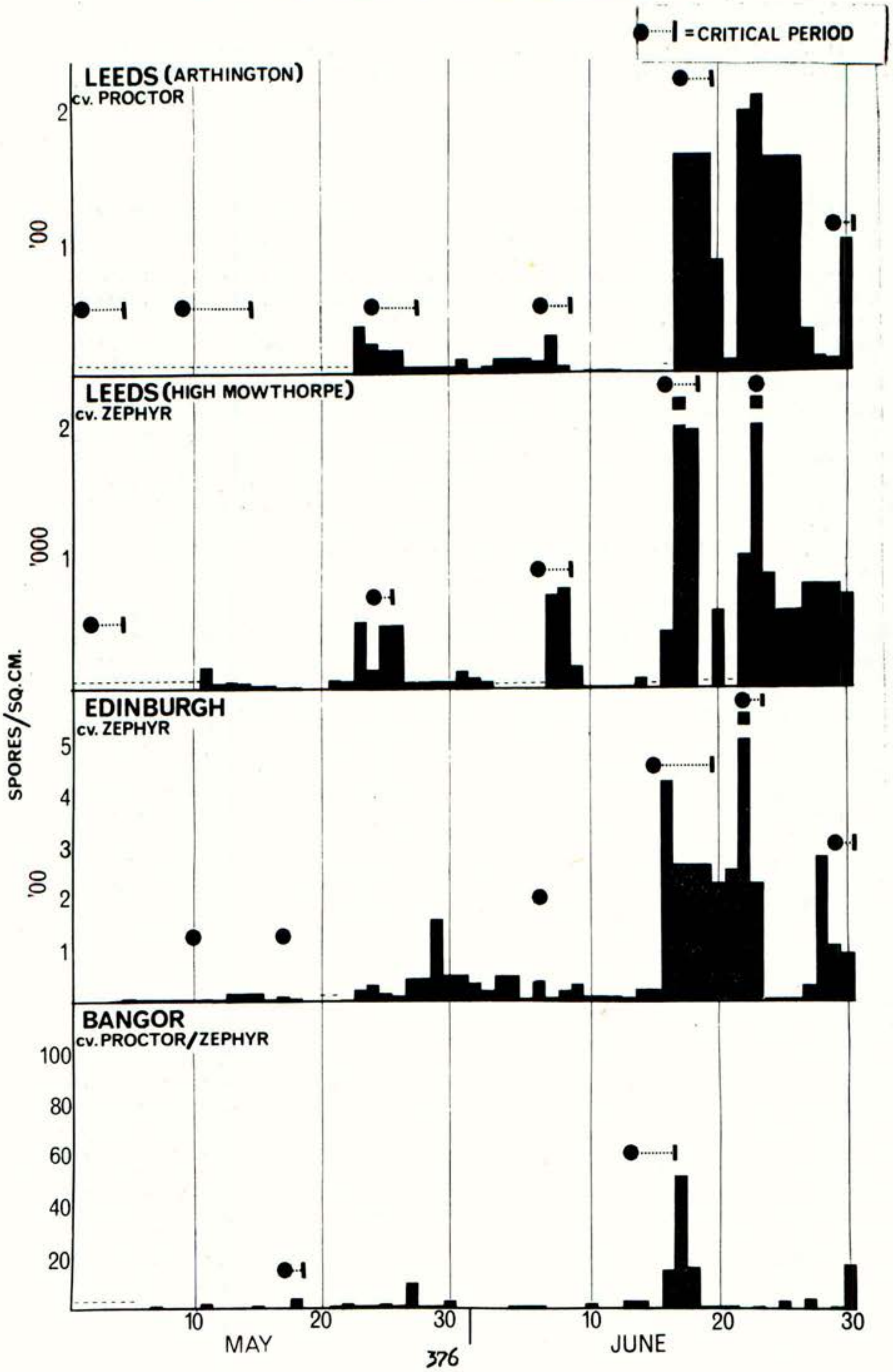
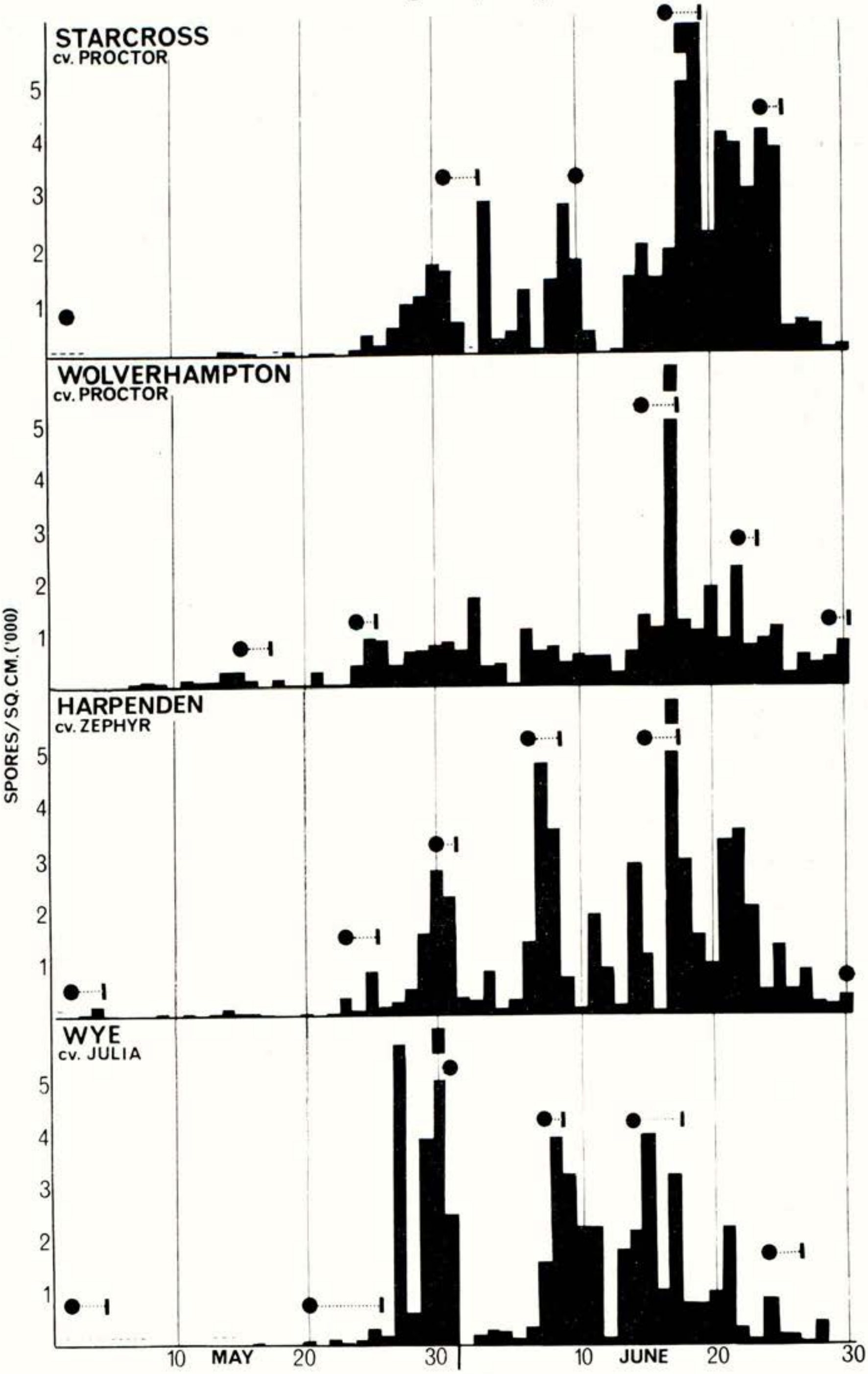


Fig. 1. (cont.)


STARCROSS
cv. PROCTOR
WOLVERHAMPTON
cv. PROCTOR
HARPENDEN
cv. ZEPHYR
WYE
cv. JULIA
SPORES/SQ.CM.('000)
1
2
3
4
5
10
MAY
20
30
10
JUNE
20
30

although a forecasting scheme will indicate periods when significant new infections are likely to occur over a wide area, it cannot make predictions for individual crops. Here, the disease itself is the ideal indicator of all the interacting factors which have affected it, and it seems probable that the level of infection in a crop must be taken into account when assessing the risk to that crop during a period when weather conditions are optimum for mildew development.

Following further work in 1973, it is hoped that a reliable forecasting scheme will be developed for use in 1974.

## Acknowledgements

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# THE APPLE SCAB OBSERVATION SERVICE IN NORTHERN IRELAND

J. Cartwright
Horticultural Centre, Loughgall, Armagh

Summary Apple Scab caused by Venturia inaequalis is the most important economic disease in commercial apple production in N. Ireland where approximately 7,000 acres of Bramley's Seedling are grown in a confined area in Co. Armagh south of Lough Neagh. Meteorological records showed that the macro-climate was fairly uniform over the entire orchard region. Ascospore discharge, hours of leaf wetness and temperature were recorded continuously from mid-March to mid-June. It was shown that accurate prediction of the occurrence of apple scab infection could be made and curative or protective spray programmes applied with greater precision than was previously possible.

## INTRODUCTION

Bramley's Seedling, the major commercial variety of apple grown in N. Ireland, is susceptible to infection by apple scab caused by Venturia inaequalis. The first chemicals used (Muskett, 1925) were protectant applications of copper, usually Bordeaux mixture. With increasing age the trees became less tolerant of copper, which caused a hardening of the leaf, and growers changed to organo-mercury compounds which were primarily curative in action. Lack of knowledge about the precise time of infection led to failures in control and often orchards were over-sprayed in an attempt to obtain clean fruit. Investigations were started in 1953 at the Horticultural Centre, Loughgall into the feasibility of providing an Apple Scab Observation Service to help growers improve their disease control.

The epidemiology of apple scab has been extensively documented with the studies and recommendations of Keit and Jones (1926), Keit and Palmiter (1937) and Mills and Laplante (1954) remaining pertinent in 1973. The major source of infection in the states of Wisconsin and New York, USA and in N. Ireland is from ascospores discharged from infected leaves overwintered on the orchard floor. In general, rainfall tends to be more persistent and temperatures lower in N. Ireland compared with other fruit-producing areas of the world. The criteria used in the Mills period forecast, (Mills and Laplante, 1954), hours of leaf wetness and temperature did not always produce infection in N. Ireland at the intensity anticipated and on some occasions no infection occurred when the Mills criteria indicated that it should.

This report considers factors involved in the operation of the Apple Scab Observation Service in N. Ireland.

## APPLE SCAB OBSERVATIONS

Approximately 98 percent of the 7,000 acres of orchards in N. Ireland are within a 10-mile radius of the Horticultural Centre, Loughgall. The topography is typically drumlin, the prevailing wind south-westerly and there are no high hills in any direction for at least 30 miles. Within this area, four meteorological posts recording hours of leaf wetness and maximum and minimum temperature have shown a high degree of uniformity over a period of 15 years. Ascospore discharge is recorded at the Horticultural Centre and the combined data examined every 24 hours. Infection period observations are broadcast within one hour of examination.

### Ascospore Trapping and Assessment

The determinents of the time of perithecial maturation, ascospore liberation and subsequent infection are extremely variable giving a range of good and poor correlations. (Keit and Jones (1926), Hirst and Stedman (1961, 1962, 1962), Anon. (1960).) Any quantitative measurement of liberated spores must be considered in conjunction with climatological and host factors pertaining at the time of measurement. Measurement in absolute terms of ascospores discharged is subject to considerable variation in sampling efficiency of the atmospheric sampling apparatus in different climatological conditions particularly wind speed and initial spore concentration. In spite of these limitations it has been found that the daily relative spore discharge from an artificial orchard floor corresponds to the concept of 'relative ascospore dose' for comparing inoculum level between orchards and seasons (Hirst and Stedman, 1960).

Each year scab-infected leaves of Bramley's Seedling are collected and a single layer of leaves measuring 0.91m square sandwiched between wire netting is laid out to simulate an orchard floor with a high initial inoculum potential. Spore trapping is by a portable volumetric trap (Gregory 1954) with an orifice of 14mm x 2 mm placed 51 mm above the infected leaves. An Edwards electric vacuum pump provides the suction with a Rotameter in the suction line adjusted to give an intake of 10 litres per minute. The spores are impacted on a glass slide coated with paraffin wax and vaseline. The slide is changed every 24 hours at 4 p.m. and five 2 mm traverses of the trace examined by projecting the miscroscope field on a 255 mm x 255 mm wall chart incorporating a 13 mm grid for rapid counting.

### Leaf Wetness

Hours of leaf wetness are measured by a surface wetness recorder (Hirst, 1957). Four of these instruments, one at each of the meteorological sites in the area, supply information on the hours of leaf wetness and intervening dry periods. The charts are changed every 24 hours between 4 and 5 p.m. The total number of hours is computed within the 24-hour period, also overlapping periods.

### Temperature

Daily recordings of maximum and minimum temperatures are made at each of the meteorological sites and a mean computed for the 24-hour period.

## METEOROLOGICAL RECORD

Table 1

Mean monthly rainfall (mm) 1965 - 1970

| | Jan | Feb | Mar | Apl | May | June | July | Aug | Sept | Oct | Nov | Dec | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| East Malling | 55.3 | 50.5 | 39.0 | 57.2 | 47.0 | 43.6 | 61.6 | 65.9 | 83.5 | 57.3 | 80.0 | 72.6 | 713 |
| Long Ashton | 75.9 | 68.0 | 46.2 | 57.7 | 82.0 | 55.8 | 97.2 | 61.1 | 89.6 | 79.4 | 103.2 | 92.4 | 901 |
| Loughgall | 66.5 | 56.6 | 50.7 | 62.7 | 63.2 | 64.2 | 52.0 | 81.5 | 73.8 | 86.0 | 74.1 | 62.7 | 794 |

Mean monthly temperature °C 1965-1970

| | Jan | Feb | Mar | Apl | May | June | July | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| East Malling | 4.1 | 3.8 | 5.9 | 7.9 | 11.6 | 14.9 | 16.0 | 16.0 | 14.2 | 11.8 | 6.3 | 4.1 |
| Long Ashton | 4.9 | 4.1 | 6.1 | 8.2 | 11.4 | 15.0 | 15.7 | 15.8 | 14.0 | 11.8 | 6.6 | 5.1 |
| Loughgall | 3.2 | 3.4 | 5.4 | 8.1 | 11.2 | 14.0 | 14.7 | 14.4 | 12.8 | 10.2 | 5.5 | 3.8 |

The records (Table 1) showed that there was less variability in the mean monthly rainfall during April and May at Loughgall compared with Long Ashton or East Malling. Temperature differences showed very little variation between the centres for each month.

In general the climate at Loughgall lacks extremes with the rainfall tending to be continuous rather than intermittent and without great variations in maximum and minimum temperature.

CROP LOSS

Table 2

Percentage fruit infected by apple scab at Loughgall 1965 - 1971

| | Percentage fruit infected | | | | | | |
|---|---|---|---|---|---|---|---|
| Treatment | 1965 | 1966 | 1967 | 1968 | 1969 | 1970 | 1971 |
| Unsprayed | 94.0 | 69.2 | 85.0 | 50 | 80 | 64.1 | 99.9 |
| Dodine≠ | 19.0 | 8.3 | 2.6 | 0.0 | + | + | 12.0 |
| Dithianon≠ | 16.0 | 1.7 | 1.1 | 0.8 | 0.6 | 2.5 | 18.0 |

≠ 10 day protectant spray programme adjusted by Apple Scab Observations
\+ The dodine formulation used was not comparable for these years

The levels of scab infection (Table 2) showed the severity in the unsprayed trees and the levels of control possible with protectant fungicides. There is also a serious loss of vigour and reduced yield from the unsprayed trees caused by premature casting of infected leaves. Such trees can take two years to recover.

EPIDEMIOLOGY

Infection by ascospores is dependent on two major factors, host receptivity and inoculum potential and infection, each of which is dependent on environmental conditions.

1. Host Receptivity

Table 3

Dates of bud burst in Bramley's Seedling at Loughgall 1965 - 1971

| | 1965 | 1966 | 1967 | 1968 | 1969 | 1970 | 1971 |
|---|---|---|---|---|---|---|---|
| March | | 28 | 16 | | | | 30 |
| April | 5 | | | 3 | 10 | 17 | |

Bud burst is generally accepted as occurring in late March or early April. The dates (Table 3) showed that it could occur as early as 16 March or as late as 17 April, a variation of 30 days. Initial susceptibility to apple scab is related to the dates of bud burst.

2. Inoculum Potential and Infection

The results showed that there was wide variation in the total numbers of spores recorded (Table 4) and that the levels of infection (Table 2) could not be related to the total recorded number of spores. Higher and lower levels of infection appeared to alternate annually whereas the spore population was more variable, so that a high level of infection was not necessarily related to a high number of spores nor a lower number of spores necessarily related to a low level of infection. The number of infection observations made in any year could not be related to the recorded total of ascospores. There were ten observations made in 1967 and 1969 with recorded spore numbers of 70,217 and 9,336 respectively. Observations in 1969 indicated continuous infection over a number of days whilst in 1967, infection periods were more widely spaced. In 1966 there were only five infection observations compared with twelve in 1968 although each year had approximately the same total recorded number of ascospores.

The period of ascospore release showed little variation except in 1970 when it was extended into June, and did not appear to have any apparent effect on the subsequent level of infection.

Table 4

Ascospore release and infection observations 1965 - 1971

| | 1965 | 1966 | 1967 | 1968 | 1969 | 1970 | 1971 |
|---|---|---|---|---|---|---|---|
| No. spores recorded | 19,032 | 20,278 | 70,217 | 20,069 | 9,336 | 49,983 | 33,206 |
| Period of spore discharge | 15 Mar - 22 May | 9 Mar - 17 May | 13 Mar - 25 May | 12 Mar - 25 May | 17 Mar - 17 May | 17 Mar - 18 June | 8 Mar - 25 May |
| Infection observations | April<br>4<br>12<br>14<br>16<br>22<br>24<br>26<br>May<br>2<br>6<br>16 | March<br>25<br>31<br>April<br>9<br>16<br>May<br>5 | March<br>22<br>25<br>April<br>1<br>19<br>20<br>23<br>May<br>3<br>9<br>13<br>16 | March<br>31<br>April<br>15<br>16<br>19<br>22<br>27<br>May<br>2<br>3<br>6<br>9<br>14<br>24 | April<br>11<br>13<br>21<br>24<br>25<br>May<br>2<br>6<br>7<br>8<br>13 | April<br>14<br>15<br>20<br>27<br>May<br>5<br>20<br>26<br>June<br>1<br>10 | April<br>16<br>19<br>22<br>23<br>May<br>6<br>7<br>15<br>16 |

## DISCUSSION

The intensive area of orchards in N. Ireland has a climate and susceptible host viz. Bramley's Seedling which are suitable for the perennation of apple scab. The crop loss from unsprayed trees is consistently high and has been since Bramley's Seedling first showed susceptibility to apple scab in 1925.

The criteria used to make an infection forecast must be easily and quickly assessed. This has been shown to be possible for physical measurements of temperature and hours of leaf wetness, the two parameters with the major influence on spore germination and infection. Spore trapping apparatus can give highly variable results with high and low levels of inoculum and at varying wind speeds. Only a sample of the spore population can be recorded and the interpretation of spore release is considered in relative numbers trapped in a given period of time.

By using an artificial orchard floor with infected leaves to give a high inoculum potential and siting it where the wind speed is minimal it is possible to obtain spore samples indicating extremes in population, corresponding to no infection potential or very severe infection potential. It is also possible to identify discrete periods of no infection or continuous infection potential.

In attempting to relate infection observations with spraying practice the extremes of no infection potential or great infection potential are probably the most important. A number of marginal situations do occur and in most cases will be absorbed (because of the short time scale involved, 7 - 8 weeks) in another infection period, or be within the effective range of fungicide application.

It was originally intended to use scab infection observations to bring precision to curative spraying with organo-mercury compounds. With increasing age the leaves of the maturing Bramley's Seedling became less tolerant of the organo-mercury compounds. To be effective, curative sprays have to be applied within a limited time after infection occurs and this is not always possible in weather conditions conducive to scab infection.

Experiments with protectant spray programmes (Table 2) have shown that dodine and diathianon can give very effective control where a 10-day interval is reduced to seven days when scab infection is assessed as severe and/or continuous. This is probably because the wet conditions necessary for severe and/or continuous infection are those which reduce the effectiveness of the fungicide on the leaf.

Involvement by growers in the Scab Observation Service has led to high standards of scab control in N. Ireland. The data necessary for infection assessment are also used in the continuous assessment of new fungicides.

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# EVALUATION OF AN ASSESSMENT KEY FOR WILT DISEASE OF PEAS

G.R. Dixon

National Institute of Agricultural Botany, Huntingdon Road, Cambridge.

Summary Two methods are described whereby pea cultivars were evaluated for resistance to *Fusarium oxysporum f. pisi* (races 1 and 2). Assessments were made either by a quick visual estimate using an assessment key as a guide or by the more lengthy process of counting numbers of healthy leaves and numbers of leaves showing symptoms of chlorosis and necrosis. Using data gathered over three years (1970-72) it was possible to establish a strong correlation between the two methods (race 1 r = 0.9815, race 2 r = 0.9868, P = 0.001). The disease assessment key has, therefore, been shown to be an accurate substitute for the counting method of assessing this vascular disease.

Sommaire Deux méthodes sont décrites pour évaluer la résistance des cultivars de pois contre *Fusarium oxysporum f. pisi* (races 1 et 2). Des estimations étaient faites visuellement avec une echelle d'intensité des maladies comme guide, ou par la méthode plus longue pour compter le nombre de feuilles qui montre des symptômes chlorotiques ou necrotiques. Il etait possible d'établir en utilisant les donnees recueilli pendant trois ans (1970-1972) une grande correlation entre les deux méthodes (race 1 r = 0.9815, race 2 r = 0.9868, P = 0.001). L'échelle d'intensité des maladies est ainsi un substitut juste ence qui concerne la méthode de compter pour estimer cette maladie vasculaire.

## INTRODUCTION

Despite their obvious subjectivity, disease assessment keys remain the most regularly used means for determining the extent of pathogen infection of host plants. This is because keys are relatively easy and convenient to use requiring no special equipment, solely a knowledge of what the disease symptoms and pathogen colonies look like under field or glasshouse conditions. Other methods have been used to assess disease, e.g. planimetry (Selman and Pegg 1957), infrared photography (Anon.1968), pyrolysis (Myers and Watson 1969) and studies of morbid anatomy and physiological fluids (Dixon and Pegg 1969, 1972). All these techniques require cumbersome and expensive equipment and are unsuited to the rapid assessment of infection in large numbers of replicated treatments.

Disease assessment was reviewed by Large (1966) and more recently by Chiarappa (1971) and James (1971). Most of the assessment keys available are concerned with farm crops in which the effects of disease are readily apparent. These keys, especially for cereal diseases, are widely available (Doling 1961; Anon. 1971). Disease keys for other crops, particularly horticultural crops, have been produced less systematically and have not been made so widely available. This is possibly because, although disease effects are readily apparent in horticultural crops, the definition of the yield loss is more difficult since yield in horticultural crops is expressed in a wide variety of ways, depending on which part of the plant is of commercial significance.

The National Institute of Agricultural Botany (NIAB) is concerned with the evaluation of agronomic characters of a number of vegetable crops. Determination of the relative levels of disease resistance in different cultivars is an important part of this programme and in consequence a number of disease assessment keys have been formulated. Use of such keys allows workers throughout the country to collect data uniformly and systematically.

Pea wilt (<u>Fusarium oxysporum f. pisi</u>) is an example of one of the more difficult diseases for which to design an assessment key. It is caused by a vascular pathogen, hence no external fungal colonies are seen until the host has been dead for some days. In the living plant external symptoms are manifested mainly as foliar chlorosis and necrosis. Stunting will occur under conditions of severe infection in which case the host is often killed before any pods are formed. An assessment key was formulated (Dixon and Doodson 1971) from visual observation of the disease on plants grown in the glasshouse. Since then the accuracy of the key has been determined and this is the subject of this paper.

## METHODS AND MATERIALS

The plants used for this work were grown in the glasshouse and inoculated as described by Dixon and Doodson (1970). Fifty plants of each of 20 cultivars were inoculated with each of the two races of <u>F. o.f. pisi</u> used in these experiments, and 50 additional plants were grown as healthy controls (i.e. 150 plants total). The cultures of <u>F. o.f. pisi</u> (races 1 and 2) have been used by NIAB over the last 15 years and regularly re-isolated from susceptible host cultivars.

Disease was assessed in two ways:-

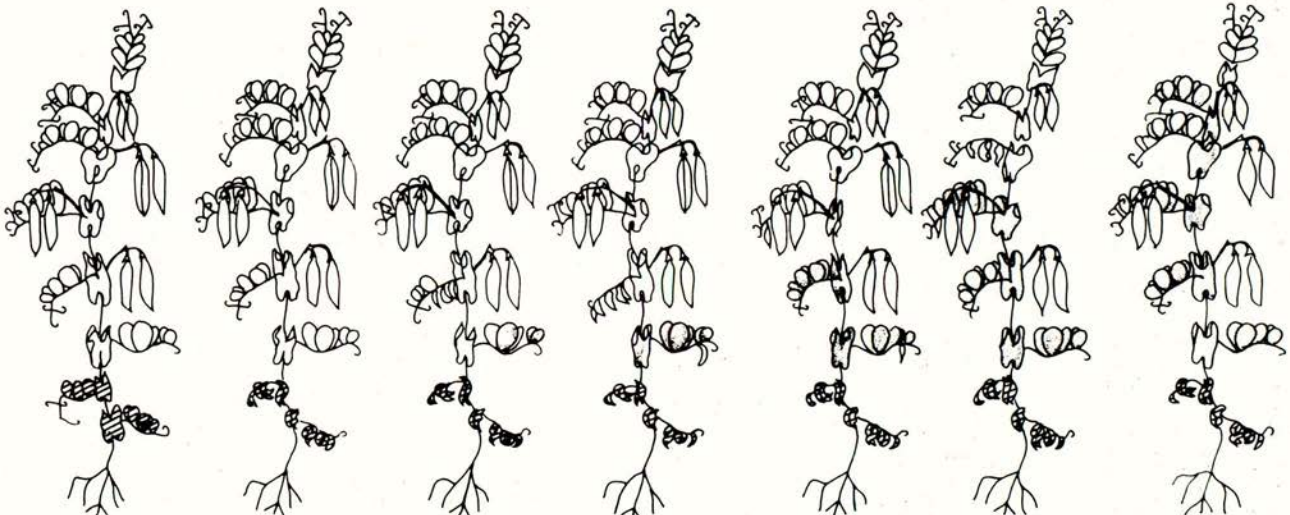
1. By visual estimate of the symptoms on each plant using the key (Fig 1) which shows the progressive increase in symptoms on the host. In resistant cultivars there was a slight chlorosis with some rolling of the basal leaves but in susceptible plants most of the leaves exhibited symptoms or the plants were completely dead (Table 1).

TABLE 1

Description of assessment key for pea wilt

| Score * | Description of symptoms |
|---|---|
| 0 | No visible symptoms |
| 0.5 | Chlorosis of basal leaves |
| 1.0 | Chlorosis and rolling of basal leaves |
| 2.0 | Necrosis and chlorosis of 5% leaves |
| 3.0 | Necrosis and chlorosis of 10% leaves |
| 4.0 | Necrosis and chlorosis of 25% leaves |
| 5.0 | Necrosis and chlorosis of 50% leaves |
| 6.0 | Necrosis and chlorosis of 75% leaves |
| 7.0 | Plant dead |

**Figure 1 ASSESSMENT KEY FOR PEA WILT**




**Disease Index: 0 - healthy plant 7 - dead plant**

* 50 plants inoculated with each race and 50 healthy controls of each cultivar were assessed, assessment started when the level of disease in a susceptible control reached 7.0 (plant dead).

2. On each plant, counts were made of the number of leaves (the whole compound leaf counting as one leaf) and the number of wilted leaves (i.e. leaves showing disease symptoms). The presence or absence of vascular discolouration (reddening of the stele) was also recorded since this character has been used to assess wilt resistance in pea cultivars (Doling - unpublished data).

## RESULTS

Experiments were carried out over three seasons (1970-72). Results from 20 cultivars, expressed as the mean of the three seasons, are given in Table 2. Correlation co-efficients and regression equations have been calculated for the mean percentage wilted leaves (y) and mean disease score (x) over the three year period and are illustrated in Fig. 2. For both races of the pathogen a highly significant correlation was obtained:-

<u>Race 1</u> $r = 0.9815 \quad (P = 0.001)$

$y = 15.063 \quad x - 9.32$

<u>Race 2</u> $r = 0.9868 \ (P = 0.001)$

$y = 15.523 \quad x = 11.40$

No significant relationship could be found between vascular discolouration and the resistance of cultivars to pea wilt.

## DISCUSSION

The data show that a visual estimate of the degree of disease symptoms on a plant obtained with a simple key can be as accurate as the long and tedious method of counting numbers of healthy and wilted leaves. This is especially important with a vascular disease where there is no external manifestation of pathogen colonies. Several authors (Waggoner and Dimond 1954; Erwin, Moje and Malca 1965; Schnathorst, Presley and Carns 1967) have attempted to assess the extent of disease caused by vascular fungi by quantitative measurements of the amount of pathogen present in host xylem vessels. This, however, pre-supposed there was a correlation between the quantity of pathogen and the symptoms expressed by the host. No such correlation has been reported in the literature. Indeed Pegg and Dixon (1969) and Dixon and Pegg (1969), in a series of treatments involving tomato cultivars and <u>Verticillium albo-atrum</u> strains, showed that host mycelial content and severity of disease development were not always related. Thus with vascular pathogens, at least, host resistance or susceptibility are not necessarily correlated with the amount of pathogen present in the host. This is unlike the situation with other diseases where the disease assessment keys measure the percentage leaf area covered by pathogen colonies. In the latter case host resistance is being correlated with the ability of the pathogen to invade host tissue and not the distress symptoms developed by the host. For any simple evaluation, however, of the effects of vascular diseases host resistance must be measured in some terms which describe the host distress symptoms; a visual assessment of these symptoms can be an accurate guide to the levels of resistance possessed by a range of cultivars.

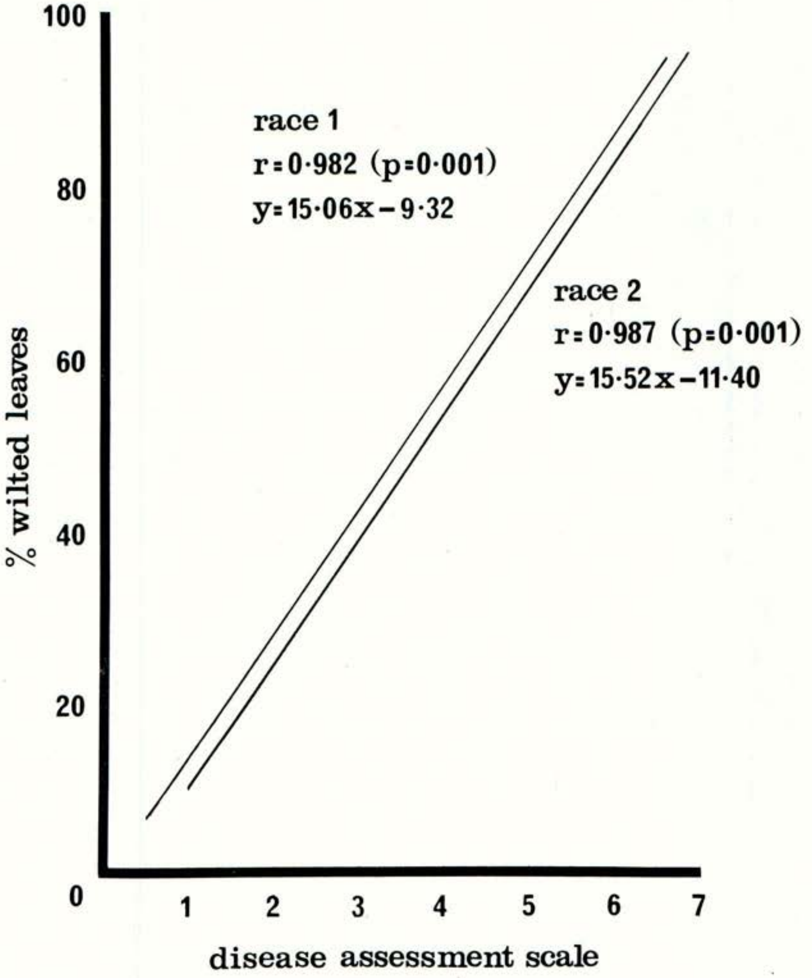
Table 2

Comparison of percentage wilted leaves and disease score in pea cultivars infected with races of *Fusarium oxysporum f. pisi* in the period 1970 - 72

| | | Means 1970 - 72 | | | |
|---|---|---|---|---|---|
| | | Race 1 | | Race 2 | |
| Cultivar | Source | Disease Score | % wilted leaves | Disease Score | % wilted leaves |
| Beagle | Hurst | 5.7 | 82.2 | 6.6 | 94.4 |
| Bonus | Asgrow | 6.5 | 90.5 | 6.0 | 76.4 |
| Canice | Hurst | 4.4 | 60.2 | 4.3 | 52.6 |
| * Dark Skinned Perfection | Brotherton | 1.9 | 21.5 | 5.1 | 64.3 |
| Dart | Asgrow | 2.4 | 28.3 | 3.3 | 39.3 |
| Elvira | Nunhem | 3.1 | 25.3 | 3.6 | 46.5 |
| Fridol | Sluis & Groot | 3.1 | 36.9 | 3.2 | 37.1 |
| Hartus | Asgrow | 3.0 | 31.9 | 5.6 | 77.7 |
| New Era | Wisconsin University | 0.5 | 6.6 | 1.0 | 10.1 |
| Orfac | Clause | 3.9 | 57.3 | 5.1 | 72.7 |
| Parade | Nunhem | 2.2 | 22.3 | 3.5 | 38.2 |
| Platinum | Asgrow | 3.1 | 37.5 | 4.5 | 59.4 |
| Preperfection | Eurolino Seeds | 1.9 | 25.3 | 4.1 | 50.0 |
| Ralca | Royal Sluis | 2.7 | 30.4 | 3.1 | 36.4 |
| Recette | Sluis & Groot | 3.6 | 41.7 | 3.7 | 45.3 |
| Sleaford Kesko | Sharpe | 2.1 | 23.4 | 5.3 | 70.7 |
| Sleaford Orbiter | Sharpe | 5.8 | 76.0 | 5.3 | 76.3 |
| Sultan | Brotherton | 3.2 | 34.3 | 4.2 | 47.3 |
| Surprise | Hurst | 3.5 | 43.9 | 5.8 | 80.2 |
| Tezieridee | Tezier | 6.5 | 92.1 | 6.5 | 90.8 |

* The stock of Dark Skinned Perfection used was Perfected Freezer 70A.

fig. 2
correlation of % wilted leaves and disease score in peas infected with <u>F.o.f. pisi</u>



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# OXAMYL - A NEMATICIDE FOR POTATOES, ONIONS AND SUGAR BEET

D.A. Allison
Du Pont (U.K.) Limited, Agrichemicals Division, Maylands Avenue, Hemel Hempstead, Hertfordshire.
C. Sinclair
Pan Britannica Industries Limited, Britannica House, Waltham Cross, Hertfordshire.
M.R. Smith
Farm Protection Limited, Glaston Park, Glaston, Uppingham, Rutland.

Summary Oxamyl (provisionally accepted I.S.O. common name thioxamyl) has been evaluated in trials since 1970 for the control of potato cyst eelworm in potatoes, stem eelworm in onions, and Docking disorder in sugar beet. Significant yield increases have been achieved. The potato cyst eelworm multiplication rate has been substantially reduced. Rates and methods of application to give optimum control with a wide margin of crop safety have been established.

Résumé Depuis 1970, des essais sont effectués avec l'oxamyl en vue de lutter contre l'anguillule de la pomme de terre, l'anguillule des tiges de l'onion et la maladie de Docking de la betterave à sucre. Des augmentations importantes du rendement ont été observées l'augmentation de l'infestation des anguillules dans le sol a été arrêtée. Les concentrations et les procédés de traitement, donnant un résultat optimum avec large marge de sécurité pour la récolte, ont été mis au point.

## INTRODUCTION

Oxamyl (provisionally accepted common name thioxamyl trade name Vydate) was first introduced into the U.K. in late 1969 from I.E. du Pont De Nemours Inc., as DPX 1410 s.c. Initial screening had indicated a high level of nematicidal and insecticidal activity. In view of the toxicity of this chemical (oral LD50 to rats 5.4 mg/kg), subsequent development concentrated on a 10% granular formulation. The dermal toxicity is relatively low (ALD to rabbits more than 5000 mg/kg) giving a good measure of operator safety.

In 1970 development concentrated on confirming activity in the principal crop areas of potatoes, sugar beet and onions. Whitehead et al (1971-73) found that potato yields were increased and eelworm populations were held at or below maintenance levels. Dunning and Winder (1971-73) carried out trials on Docking disorder sites and obtained yield increases at some sites and Winfield, Murdoch and John (1971) indicated that onion yields could be increased following application of the chemical at drilling.

A wide range of additional research has been carried out in a variety of crops to supplement and complement our own work, indicating valuable potential uses. The product was marketed for use on potatoes and onions in 1973.

The aims of the trials presented in this report were to find out whether treatment with oxamyl would result in an increase in yield in the presence of nematodes. In potatoes it was decided to investigate the effect of treatment on the eelworm populations of Heterodera rostochiensis and H. pallida. Yield increases through control of Docking disorder caused mainly by Trichodorus and Longidorus spp. would be investigated in sugar beet and of stem eelworm or 'Bloat', Ditylenchus dipsaci, in onions.

## POTATOES

### METHOD AND MATERIALS

Small plot and grower trials were conducted during 1971-73. In 1971 the purpose was to compare a range of rates 0, 2.5, 5.0, and 10.0 lb a.i./ac applied in-furrow, in comparison with broadcast incorporated treatment. In-furrow applications were made by band placement by hand in the furrow with the potatoes at planting. In 1972 rates were 0, 2.0, 3.5, 5.0 and 10.0 lb a.i./ac, applied broadcast and incorporated by rotovation before planting. In 1973, rates were 0, 3.0 and 5.0 lb a.i./ac comparing different methods of incorporation. The granules were applied by pepperpot or knapsack granule applicator in small plot trials and by various mechanical granule distributors in grower trials. In small plot trials treatments were replicated at least 4 times in randomised blocks. A range of soil types and potato varieties (eelworm susceptible and resistant) were selected. Most trials were sampled for yield data and for estimates of eelworm populations pre-planting and post-harvest.

### RESULTS

See tables 1 to 5

### DISCUSSION

In 1971 results showed that broadcast treatment was superior to in-furrow treatment with regard to both yield and eelworm control. Eelworm multiplication on untreated plots was low, presumably due to natural density dependent factors acting on the high initial populations.

In 1972 a wider range of trial sites was selected. In the replicated trials increasing rates generally resulted in increasing yields. On light soils there was little difference between 2.0, 3.5, and 5.0 lb a.i./ac. On organic soils lower rates gave only slight yield increases and yield continued to increase up to 10 lb a.i./ac.

In the grower trials the best response was gained on silt soils but yields generally were low. On organic sites untreated yields were high but nevertheless oxamyl treatment increased yields by over 2 tons to the acre (16.7%).

Eelworm counts in small plot trials indicated that 5.0 lb/ac oxamyl populations at maintenance levels on light soils and reduced population increase by 75% on silt soils and 50% on organics.

Maris Piper which is resistant to H. rostochiensis responded to oxamyl treatment with yield increases when grown in land infested with this species.

In conclusion the potato trials demonstrated that valuable yield increases were achieved from 5.0 lb/ac on all soil types although lower rates were effective on light soils. The reducing effect on eelworm population growth as indicated by the multiplication factor was most marked on light mineral soils and least

Table 1

Replicated Trials - Potatoes 1971

Ware Yield Tons/Acre

| Treatment lb a.i./ac | Silts (3) Mean Yield | Silts (3) % Increase | Organics (4) Mean Yield | Organics (4) % Increase | Mean Yield | Mean % Increase |
|---|---|---|---|---|---|---|
| Untreated Control | 4.2 | - | 4.4 | - | 4.3 | - |
| 2.5 in furrow | 6.1 | 45 | 7.0 | 59 | 6.6 | 54 |
| 5.0 in furrow | 5.9 | 40 | 7.0 | 59 | 6.5 | 51 |
| 10.0 in furrow | 5.9 | 40 | 7.1 | 61 | 6.6 | 54 |
| 2.5 broadcast | 6.1 | 45 | 7.4 | 68 | 6.8 | 59 |
| 5.0 broadcast | 5.8 | 38 | 9.2 | 95 | 7.4 | 72 |
| 10.0 broadcast | 6.8 | 62 | 9.2 | 109 | 8.2 | 91 |

Table 2

Effect of Oxamyl on Eelworm numbers

| Treatment lb a.i./ac | Multiplication Factor Silts (2) | Organics (4) | Mean |
|---|---|---|---|
| Untreated Control | 4.5 | 1.7 | 2.6 |
| 2.5 in furrow | 3.7 | 2.0 | 2.6 |
| 5.0 in furrow | 3.0 | 1.6 | 2.1 |
| 10.0 in furrow | 3.3 | 1.9 | 2.4 |
| 2.5 broadcast | 2.7 | 1.8 | 2.0 |
| 5.0 broadcast | 2.5 | 1.3 | 1.7 |
| 10.0 broadcast | 2.2 | 1.3 | 1.6 |

Table 3

Replicated Trials - Potatoes 1972

Ware Yield Tons/Acre

| Treatment lb a.i/ac | Light Soils (2) Mean Yield | Light Soils (2) % Increase | Silt Soils (6) Mean Yield | Silt Soils (6) % Increase | Organic Soils (4) Mean Yield | Organic Soils (4) % Increase | Mean Yield | Mean % Increase |
|---|---|---|---|---|---|---|---|---|
| Untreated Control | 10.3 | - | 8.1 | - | 9.3 | - | 9.2 | - |
| 2.0 | 12.5 | 20.7 | 10.2 | 26 | 9.9 | 6.4 | 10.5 | 14.1 |
| 3.5 | 12.5 | 21.2 | 10.8 | 33 | 10.2 | 9.6 | 10.9 | 18.4 |
| 5.0 | 12.9 | 24.6 | 11.5 | 42 | 10.5 | 12.9 | 11.4 | 23.9 |
| 10.0 | 13.9 | 34.3 | 11.2 | 38 | 11.5 | 23.6 | 11.7 | 27.1 |

satisfactory on organic soils.

It must be concluded that oxamyl treatment would not only enable potato growers to achieve greater potential from their good potato land infested with eelworm but also reduce the rate of eelworm population growth thus giving benefit to the subsequent potato crop.

Table 4

Effect of Oxamyl on Eelworm numbers

| Treatment lb a.i./ac | Multiplication Factor Light Soils (1) | Silts (6) | Organics (3) | Mean |
|---|---|---|---|---|
| Untreated Control | 4.4 | 12.3 | 11.9 | 10.3 |
| 2.0 | 2.6 | 5.4 | 7.2 | 5.2 |
| 3.5 | 1.4 | 3.8 | 7.5 | 4.2 |
| 5.0 | 1.0 | 3.0 | 5.9 | 3.3 |
| 10.0 | 1.0 | 2.2 | 5.2 | 2.7 |

Table 5

Grower Trials - Potatoes 1972

Ware Yield (Tons/ac) and Eelworm numbers (eggs/gm)
Light Soils (Mean of 4 sites)

| | Av. Yield | % Increase | Mult. Factor |
|---|---|---|---|
| Untreated Control | 13.7 | - | 11.9 |
| Oxamyl 5.0 lb a.i./ac | 17.4 | 27 | 0.5 |
| Silt Soils (mean of 5 sites) | | | |
| Untreated Control | 7.5 | - | 4.4 |
| Oxamyl 5.0 lb a.i./ac | 11.4 | 52 | 2.6 |
| Organic Soils (mean of 8 sites) | | | |
| Untreated Control | 13.1 | - | 5.2 |
| Oxamyl 5.0 lb a.i./ac | 15.3 | 16.7 | 3.4 |
| Mean | | | |
| Untreated Control | 11.6 | - | 5.6 |
| Oxamyl 5.0 lb a.i./ac | 14.7 | 26.7 | 2.8 |

ONIONS

## METHOD AND MATERIALS

In 1972 both small plot replicated and grower scale trials were laid down. Rates varied from 0.75 to 8.5 lb a.i./ac on mineral and organic soils. Oxamyl was applied at drilling both in the seed furrow and by the bow-wave technique.

## RESULTS

See table 6.

## DISCUSSION

The replicated trials were laid down in fields where onions had a recent history of eelworm infestation. In one trial there was an indication of reduced seedling emergence with in-furrow treatment. Although there was no sign of phytotoxicity or reduced stand in any of the other trials, it was concluded that bow-wave treatment would be safer under a wide range of conditions.

In the replicated trials yields were low due to adverse growing conditions. However oxamyl treatment produced a considerable yield response. In the 5 grower trials on silts and clay loams, yields were increased from 17.4 tons on the untreated plots to 22.9 tons by treatment with 1.5 lb a.i./ac oxamyl (31.6% increase) and to 23.2 tons (33.3%) with 3.0 lb.

It was concluded that on mineral soils early protection of the onion seedling with either 1.5 or 3.0 lb a.i./ac could result in a significant increase in final yield, the higher rate affording better protection where heavy eelworm pressure was expected. Limited data not presented have indicated that oxamyl treatment would not prevent spread of infection during storage at the end of the season, but will not increase percentage loss.

Further work in 1973 was carried out to investigate the effects of oxamyl treatment on organic soils, and to confirm optimum dosage rates. This will be presented at the Conference.

Table 6

Yield Results Onion Trials Tons/Acre

| Treatment lb a.i/ac | Replicated Trials | | | Grower Trials | | | | | Mean Yield | % Increase |
|---|---|---|---|---|---|---|---|---|---|---|
| Control | 0.0 | 1.6 | 1.6 | 21.8 | 21.9 | 9.8 | 12.7 | 20.7 | 17.4 | - |
| 0.75 | - | 6.9 | - | - | - | - | - | - | - | - |
| 1.5 | - | 5.4 | 5.0 | - | - | - | 21.8 | 24.0 | 22.9 | 31.6 |
| 2.3 | 3.5 | - | - | - | - | - | - | - | - | - |
| 3.0 | - | 2.1 | 5.8 | 26.6 | 19.6 | - | 23.3 | - | 23.2 | 33.3 |
| 4.3 | 5.4 | - | - | - | - | 23.9 | - | - | (23.9) | (37.0) |
| 6.0 | - | - | 5.6 | - | - | - | - | - | - | - |
| 8.5 | 6.8 | - | - | - | - | - | - | - | - | - |

SUGAR BEET

## METHOD AND MATERIALS

In 1972 small plot replicated and grower scale trials were laid down to investigate the effect of oxamyl on yield in Docking disorder fields. Application was made at drilling in the seed furrow using a granule applicator mounted on the seed drill. In the replicated trials, rates were 0, 0.37, 0.5, 0.75, 1.0, 1.5 and 2.0 lb a.i./ac replicated 5 times in randomised blocks. In the grower trials, rates were 0, 0.37, 0.6, 0.75, and 1.0 lb a.i./ac.

## RESULTS

See table 7 for yield data.

## DISCUSSION

There was no effect on germination or seedling emergence up to 2.0 lb a.i./ac and it was concluded that oxamyl was well tolerated by beet plants thus demonstrating a good safety margin.

In the replicated trials Docking disorder was scarce and there were no significant yield differences. Although Docking disorder was also mild in the grower trials, yield increases were recorded in 7 of the 9 trials. In some cases yield increases occurred where there had been little or no visual effect following treatment. In one of the 3 trials where telone was used a higher yield than oxamyl occurred but at another site yields were similar and at the final site oxamyl outyielded telone by 2.4 tons.

The incidence of Fanging, a major Docking disorder symptom, was considerably reduced by oxamyl in 3 of the 4 replicated trials.

These yield and root responses were considered sufficiently encouraging and further grower trials have been laid down in 1973 to confirm optimum rates under more testing climatic and Docking disorder conditions. It is hoped results will be available to report at the Conference.

Table 7

Yield Results from Sugar Beet Growers Trials

Tons/Acre

| Treatment lb a.i/ac | | | | | | | | | | Yield | % Increase |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | 19.2 | 11.1 | 17.4 | 12.2 | 20.4 | 15.5 | 17.0 | 15.8 | 15.1 | 16.0 | - |
| 0.37 | - | - | - | - | 20.1 | 17.9 | 16.3 | 16.8 | 18.2 | 17.9 | 11.8 |
| 0.6 | 20.4 | 14.4 | 19.8 | 12.6 | - | - | - | - | - | 16.8 | 5.0 |
| 0.75 | - | - | - | - | 20.0 | 20.5 | 15.7 | 16.7 | 18.3 | 18.3 | 14.3 |
| 1.0 | 20.6 | 15.5 | 21.1 | 16.1 | - | - | - | - | - | 18.3 | 14.3 |
| Telone | - | - | 18.7 | 17.9 | - | - | - | - | 18.9 | 18.5 | 15.6 |

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Proceedings 7th British Insecticide and Fungicide Conference (1973)

# RESULTS OF 1972 U.K. TRIALS WITH COAL BASED ALDICARB ON SUGAR BEET, POTATOES AND BULB ONIONS

D. H. Bartlett and R. J. Roscoe,
Murphy Chemical Ltd, Wheathampstead, Herts.

D. Wilson and D. H. Spencer-Jones,
Duphar-Midox Ltd. Ashford, Kent.

Summary Field trials in 1972 compared a new coal based granular formulation of aldicarb, with the previously marketed corn cob based formulation, for the control of Docking disorder of sugar beet, potato root eelworm in potatoes and stem eelworm in bulb onions. Incidence of Docking disorder was only slight but the trials on potatoes and bulb onions demonstrated the excellent and comparable nematicidal properties of both formulations of aldicarb. Increases in yield of potatoes were up to 114% and in onions were up to 908%. The aldicarb coal formulation at all rates tested also improved onion storability.

Résumé Des essais de plein champ réalisés en 1972 ont comparé une nouvelle formulation d'aldicarbe granulés à base de charbon avec la formulation sur rafle de maïs vendue précédemment pour lutter contre le "Docking Disorder" (Longidorus et Trichodorus spp.) sur betteraves à sucre, contre Heterodera rostochiensis sur pommes de terre et contre les nématodes des bulbes d'oignon (Ditylenchus dipsaci). L'importance du "Docking Disorder" a été faible mais les essais sur pommes-de-terre et oignons ont mis en évidence les propriétés nématicides excellentes et comparables des deux formulations d'aldicarbe. Les augmentations de rendement ont atteint 114% pour les pommes-de-terre et 908% pour les oignons. La formulation d'aldicarbe sur granulés à base de charbon a amélioré la conservation des oignons pour l'ensemble des doses expérimentées.

## INTRODUCTION

The results of many field trials using aldicarb, formulated on corn cob as a 10% a.i. granule, have been reported since 1967. In particular Dunning and Winder (1969) reported increased yield of sugar (59 to 91%) from sugar beet affected by Docking disorder caused by Longidorus and Trichodorus spp. Dunning and Winder (1973) also showed that coal based aldicarb gave control of green aphids (Myzus persicae), pigmy beetle (Atomaria linearis) and millipede (Boreoiulus tenuis). Control of M. persicae persisted for more than 14 weeks giving a significant decrease in virus yellows, equal in effect to that given by the corn cob granules.

Whitehead and Tite (1969, 1971), Whitehead (1971), Pain and Hague (1971) and Dash et al (1969) have shown that aldicarb also gave good control of potato cyst eelworm (Heterodera rostochiensis) resulting in yield increases of up to 289%. Dash et al (1969) also found that excellent control of M. persicae was maintained in the potato crop for 14-17 weeks.

Work by Winfield et al (1971) showed that a high level of control of stem eelworm (Ditylenchus dipsaci) in bulb onions was given by aldicarb. This resulted in greatly increased yield.

Aldicarb formulated on a corn cob granule is widely sold as Temik in many parts of the world. In the U.K., however, the attractant qualities to birds of corn cob granules with the consequent potential hazard to wildlife when impregnated with aldicarb has been recognised. This has resulted in the Union Carbide Corporation, the manufacturers of aldicarb, developing a formulation based on ground coal which is non-attractant to birds, specifically for the U.K. market. This formulation was field tested, in comparison with the corn cob granules in 1972, and this report concerns the results of the trials carried out on sugar beet, potatoes and bulb onions.

## METHODS AND MATERIALS

Sites were selected in the case of the sugar beet and potato trials based on a history of poor crops and high nematode counts. The onion trials were carried out at rented sites where there had been damage to onions in 1971.

Trial details are found in Table 1.

Table 1
Trial details

| Trial no. | Location | Soil type | Crop | Replicates | Plot size $yd^2$ | Application | Dates of assessment | Dates of harvest |
|---|---|---|---|---|---|---|---|---|
| 1 | Norfolk | Sandy loam | Sugar beet | 3 | 60 | 24/3 | 21/6 and 27/7 | 11/10 |
| 2 | " | " | " " | 3 | 60 | 24/3 | 21/6 and 27/7 | 18/10 |
| 3 | " | " | " " | 4 | 600 | 5/4 | 5/5 and 21/6 | 2/10 |
| 4 | Yorks | " | " " | 8 | 600 | 6/4 | 12/5 and 20/6 | 2/11 |
| 5 | Lincs | Silt loam | Potatoes | 4 | 1000 | 22/4 | 1/6 and 25/7 | 26/9 |
| 6 | " | " " | " | 3 | 1000 | 28/3 | 20/6 and 28/7 | 4/10 |
| 7 | Jersey | " " | " | 4 | 10 | 21/3 | - | 13/6 |
| 8 | " | " " | " | 4 | 10 | 22/3 | - | 14/6 |
| 9 | Norfolk | Sandy loam | Onions | 4 | 150 | 17/3 | 4/5 and 7/7 | 15/9 |
| 10 | Ely | Organic | " | 2 | 300 | 23/7 | 5/5 and 7/7 | 10/10 |
| 11 | Lincs | Silt loam | " | 4 | 80 | 17/4 | 24/4 and 5/7 | 9/10 |
| 12 | " | " " | " | - | 25 | 5/4 | 20/6 and 28/7 | 5/10 |
| 13 | " | " " | " | - | 25 | 5/4 | 20/6 and 28/7 | 5/10 |

The onion seed used in trials 9, 10 and 11 (var. Produrijn) and in trials 12 and 13 (var. Rijnsburger) was pre-treated with methyl bromide.

Aldicarb (Temik 10G Aldicarb Pesticide) was used as 10% a.i. coal based granules in comparison with 10% a.i. corn cob granules.

Application to all trials was made using a Horstine-Farmery microband granule applicator, with the exception of numbers 7 and 8 where a 'pepper pot' technique was used. In all instances treatments were to the row only. In the case of the sugar beet and onion trials the applicator was mounted on a precision drill and the granules were placed in a one to two inch band with the seed. For potato trial no. 6 the outlet was raised and arranged to give a wider band of granules which mixed with the soil as the furrows closed, while for potato trial 5 the outlets were fitted with 'fish tails' mounted behind each ridging body placing the granules in a six inch band on and around the potato tuber.

Trials, 3, 4, 9, 10 and 11 were applied using a combination of different rotors in each hopper enabling 4 different rates of aldicarb to be applied with one untreated at the same time on a five row drill. The other trials were applied as bouts of each separate treatment.

Assessments of sugar beet and onion stand were made by counting 50 and 20 inches of row respectively. Vigour assessments where best treatment = 100% were also made. Sugar beet, potato and onion harvest yields were taken from randomised 11 yard lengths of row, except for potato trials 7 and 8 where 2 x 3 yard lengths of row were taken from each plot. No nematode counts before or after treatment were taken.

One hundred onions were taken after harvest from trials 12 and 13 and were barn stored and assessed for rots after 10 and 26 weeks.

## RESULTS

### Sugar beet

Emergence counts showed very little difference in seedling numbers between treatments. Data are therefore not presented.

Vigour assessments also showed very little difference between treatments except trial 1 where three months after application vigour differences could easily be seen. An attack of mangold fly (*Pegomya betae*) occurred in trial 4.

Data are found in Table 2.

Table 2

Trial 1 sugar beet % vigour; trial 4, % control of mangold fly 11 weeks after treatment

| aldicarb lb a.i./ac | trial 1 sugar beet % vigour | trial 4 % control of mangold fly |
|---|---|---|
| 0.25 coal | - | 88 |
| 0.5 coal | 100 | 80 |
| 0.75 coal | 87 | 96 |
| 1.0 coal | 82 | 96 |
| 1.0 corn cob | 95 | 98 |
| untreated | 71 | 0 |

The only trial which showed large yield differences between treatments was again trial 1. Yield figures for all trials are given in Table 3.

Table 3

Yield of sugar beet root as lb per 11 yd of row*

| Treatment lb a.i./ac | 1 | 2 | 3 | 4 | Mean | % untreated |
|---|---|---|---|---|---|---|
| 0.5 coal | 29.1 | 49.6 | 62.4 | 53.6 | 48.7 | 103.2 |
| 0.75 coal | 28.5 | 49.8 | 60.3 | 52.6 | 47.8 | 101.3 |
| 1.0 coal | 25.4 | 49.7 | 66.2 | 53.6 | 48.7 | 103.2 |
| 1.0 corn cob | 31.1 | 46.4 | 67.5 | 56.1 | 50.3 | 106.6 |
| untreated | 22.9 | 49.2 | 64.9 | 51.7 | 47.2 | 100.0 |
| L.S.D. (P = 0.1) | 8.3 | 4.1 | N.S. | 1.5 | | |

* 10 lb/11 yd of row is approximately equivalent to 4 ton/ac.

Potatoes

In trials 5 and 6 on main crop potatoes there were no clear visual differences in crop vigour during the growing season. Yield results are found in Table 4. Yield results for trials carried out on early potatoes in Jersey are found in Table 5.

Table 4

Effect of aldicarb on the yield of main crop potatoes

| Trial No. | Potato var. | Treatment lb a.i./ac | Yield ware potatoes ton/ac | Yield as % untreated |
|---|---|---|---|---|
| 5. | Pentland Crown | aldicarb 2.0 coal | 18.7 | 100.5 |
| | | " 2.5 coal | 19.8 | 106.9 |
| | | " 3.0 coal | 20.3 | 109.0 |
| | | " 2.5 corn cob | 19.1 | 102.6 |
| | | phorate 1.4 | 17.5 | 94.2 |
| | | untreated | 18.6 | 100.0 |
| L.S.D. (P = 0.1) | | | 2.4 | |
| 6. | King Edward | aldicarb 3.0 coal | 14.1 | 116.9 |
| | | " 3.0 corn cob | 13.4 | 111.0 |
| | | untreated | 12.1 | 100.0 |
| L.S.D. (P = 0.1) | | | 1.34 | |

Table 5

Effect of aldicarb on the yield of early potatoes

| Treatment lb a.i./ac | | Ulster Sceptre (Trial 7) Yield as ton/ac | Yield as % untreated | Jersey Royal (Trial 8) Yield as ton/ac | Yield as % untreated |
|---|---|---|---|---|---|
| aldicarb | 1.0 coal | 8.1 | 136.6 | 3.82 | 277.5 |
| " | 1.5 coal | 7.86 | 131.9 | 3.96 | 288.0 |
| " | 2.0 coal | 9.94 | 166.8 | 4.38 | 319.3 |
| " | 1.5 corn cob | - | - | 4.47 | 324.7 |
| untreated | | 5.95 | 100.0 | 1.38 | 100.0 |
| L.S.D. (P = 0.1) | | 2.88 | | 1.41 | |

Bulb onions

The mean emergence counts of trials 9, 10 and 11 are found in Table 6 along with plant stand, damaged plant number and yield figures for trials 9 and 10. Trial 11 was lost due to a severe attack of onion rot.

Plant stand, yield and storage figures for trials 12 and 13 are found in Table 7.

Table 6

Mean onion stand, damaged plant number and yield figures for trials 9 and 10

| Treatment lb a.i./ac | Plant/20 inches row *5-7 weeks | 15 weeks | % eelworm damaged 15 weeks | Yield ton/ac | Yield as % untreated |
|---|---|---|---|---|---|
| aldicarb 0.25 coal | 17.2 | 15.0 | 4.0 | 23.56 | 815 |
| aldicarb 0.5 coal | 21.5 | 18.8 | 0.6 | 29.05 | 1005 |
| aldicarb 0.75 coal | 21.4 | 17.4 | 1.2 | 29.12 | 1008 |
| aldicarb 1.0 coal | 18.6 | 15.0 | 1.6 | 25.79 | 892 |
| aldicarb 1.0 corn cob | 17.2 | 16.8 | 0.6 | 29.12 | 1008 |
| untreated | 17.4 | 9.7 | 30.9 | 2.89 | 100 |

* mean of trials 9, 10 and 11

Table 7

Mean onion stand, yield and storage figures for trials 12 and 13

| Treatment lb a.i./ac | Plants/20 inches row 12 weeks | 17 weeks | Yield ton/ac | Yield as % untreat. | % storage rots after 10 weeks | 26 weeks |
|---|---|---|---|---|---|---|
| aldicarb 0.5 coal | 7.4 | 6.7 | 16.22 | 414 | 12.0 | 22.0 |
| aldicarb 1.0 coal | 8.9 | 9.7 | 17.10 | 436 | 6.0 | 16.0 |
| aldicarb 1.5 coal | 10.5 | 10.5 | 19.82 | 505 | 0.0 | 5.0 |
| untreated | 5.0 | 5.1 | 3.92 | 100 | 41.7 | 63.3 |

## DISCUSSION

### Sugar beet trials

Due to the dry spring, Docking disorder was not generally a problem in 1972. This was reflected in the fact that in only one of the four trials carried out was there a significant yield increase following the use of aldicarb (Table 3) compared with the large increases that Dunning and Winder obtained (1969-1970). The season was also notable for its very low aphid incidence so that no information on virus yellows control was obtained from these trials.

One trial (Table 2) did show good control of mangold fly obtained with all rates of aldicarb used.

In all trials on sugar beet the coal formulation of aldicarb appeared to be as effective as the corn cob formulation.

### Potato trials

Trials 5 and 6 were carried out at sites where potato cyst eelworm was known to be present but attack was slight in that there was no foliar vigour difference between treatments. However, all the aldicarb treatments out-yielded the untreated (Table 4) and in trial 5 it was noted that in the aldicarb treated plots the root growth was much stronger than in the phorate or untreated plots in which some cysts were also found. The level of aphid incidence was too low in these trials for an assessment to be made.

The two trials carried out on early potatoes in Jersey, showed dramatic yield increases following treatment with aldicarb. In the case of the variety Jersey Royal in trial 8 (Table 5) the aldicarb treatments showed yields of more than two and a half times the untreated.

In the three trials where aldicarb coal base was compared with the corn cob base there appeared to be equal effectiveness in increasing potato yield.

### Bulb onion trials

In the four onion trials successfully taken through to yield a high attack of stem eelworm was encountered. Both coal and corn cob formulations in trials 9 and 10 (Table 6) and the coal formulation in trials 12 and 13 (Table 7) showed increases in plant stand over the untreated which were later reflected in yield increases of between 314-908%.

Trials 12 and 13 (Table 7) also demonstrate that aldicarb coal formulation, particularly at the 1.5 lb a.i./ac rate, improved the storability of the onions by reducing storage rots caused by stem eelworm to 5% as compared with 63.3% for the untreated.

In sugar beet, potato and bulb onion trials where the level of eelworm attack was sufficient to reduce plant stand or yield, aldicarb coal formulation was equally effective as the corn cob formulation.

## Acknowledgements

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# EXPERIMENTS WITH DAZOMET FOR THE CONTROL OF POTATO CYST EELWORM IN POTATO CROPS

H. C. May & R. Osborne
BASF United Kingdom Limited, Lady Lane, Hadleigh, Ipswich, Suffolk

Summary Replicated field trials were carried out in 1971 and 1972 to assess the degree of PCE control using dazomet. Different rates of the chemical were applied in early and late autumn in fields of known PCE infestation where potatoes would be planted the following year.

The chemical was applied to the soil surface, incorporated with a rotary cultivator and left without sealing until the following spring. The potatoes were then planted in the normal way.

Assessments showed that dazomet substantially reduced the multiplication of PCE populations and also gave increases in yield of potatoes. Dazomet 224 kg/ha increased PCE populations by an average 3.5 x in 1972 compared to 14 x on the untreated areas.

There were only marginal differences between rates of chemical used and times of application. Good control of perennial weeds and autumn germinating weeds was also obtained with all dazomet treatments.

Résumé Des assais répétés furent effectués en 1971 et 1972 pour évaluer l'activité du dazomet contre les cystes de l'anguillule de la pomme de terre. Différentes concentrations du produit chimique furent utilisées, en debut et fin d'automne, sur des champs à infestation connue. Des pommes de terre devaient être plantées dans ces champs l'année suivante. Le produit chimique fut répandu sur la surface du sol, puis incorporé à l'aide d'un rotovator et laissé tel quel jusqu'au printemps suivant. Les pommes de terre furent ensuite plantées selon la méthode habituelle.

Les résultats montrèrent que le dazomet diminuait la multiplication des cystes de façon interessante et augmentait le rendement. Il y avait seulement des différences légères entre les concentrations utilisées et les périodes d'application. Une augmentation de population de 3.5 fois était observée après utilisation du dazomet (224 kg/ha) en comparison avec une augmentation de population de 14 fois sur les parcelles témoins non traitées.

Tous les traitements avec dazomet donnèrent de bons résultats dans la lutte contre les mauvaises herbes vivaces et les mauvaises herbes à germination automnale.

## INTRODUCTION

Dazomet is a soil sterilant which is used both under glass and outdoors in highly intensive cropping systems. It is formulated as a prill which is applied to the soil surface, incorporated into the soil and then sealed with polythene. Once the chemical is mixed with the soil it breaks down to form methyl-isothiocyanate gas which is the active sterilising agent. The polythene seal prevents escape of the gas and maintains a toxic concentration within the soil.

Under these circumstances, used at a rate of 380 kg/ha, it is known to have a considerable effect against Potato Cyst Eelworm. (Heterodera rostochiensis and H. pallida.

Trials were carried out in 1968-69 to evaluate the effect of dazomet when used at lower rates, applied in late autumn, without sealing the soil surface (Whitehead and Tite 1970). It was hoped that the lower temperatures and higher rainfall in late autumn would overcome the need for polythene sealing which would be impractical on a large scale outdoors. Applications at this time would also make pre-planting gas release cultivations unnecessary. The results of these trials showed that dazomet at 224 kg/ha gave good control of PCE and also increased the yield of potatoes.

Trials were carried out by BASF United Kingdom Limited in 1971-1972 to further evaluate these results on a range of mineral soils.

Sites were chosen where PCE was known to exist in fairly high populations and where potatoes would be cropped in the following spring.

The results of these trials are presented.

## METHOD AND MATERIALS

Dazomet contains 98% active ingredient formulated as a prill. All 1972 trials were of a randomised block design with three replicates and each plot measured 8 x 20 yds. (Trials in 1971 were only twice replicated). All trial sites were ploughed and cultivated to give a good even tilth before application.

Treatments were applied with a Horstine Farmery dazomet applicator which spread the chemical evenly over the soil surface. Incorporation was carried out using a Howard Rotary Cultivator fitted with L - shaped rotors. The cultivator was set to give maximum rotor speed (540 r.p.m.) and maximum depth. (In practice, depth of incorporation varied between 5 - 8 in. of compacted soil depending on soil type.)

After incorporation the plots were left until the following spring when the normal planting operations were carried out. Care was taken to avoid going deeper than the treated area when building the potato ridges.

PCE assessments were carried out by the Ministry of Agriculture ADAS Entomology divisions. Total number of eggs/g of soil was estimated for each plot pre-treatment and post-harvest.

Assessments for potato haulm and tuber diseases were carried out by the ADAS Plant Pathology division. Five plants from each plot were assessed for haulm diseases and 100 tubers from each treatment were assessed for tuber diseases.

Yield of potatoes was assessed by taking three rows from each plot and recording the total weight of tubers produced.

Table 1

Trial site details

| Trial Site No. | Soil Type | Cultivar | Row Width | Date Planted | PCE Count* (eggs/g of soil) |
|---|---|---|---|---|---|
| 1971 | | | | | |
| 1. | Coarse sandy loam | King Edward | 28" | 3.4.71 | 42 |
| 2. | Silty clay loam | Pentland Crown | 28" | 6.4.71 | 22 |
| 1972 | | | | | |
| 3. | Loamy medium sand | Pentland Crown | 28" | 20.4.72 | 24 |
| 4. | Loam | Majestic | 28" | 28.4.72 | 22 |
| 5. | Coarse sand | Pentland Crown | 28" | 14.4.72 | 31 |
| 6. | Fine sandy loam | Pentland Crown | 30" | 7.4.72 | 6 |
| 7. | Loamy coarse sand | Ulster Chieftain | 28" | 7.3.72 | 34 |
| 8. | Silty loam | Pentland Crown | 30" | 4.4.72 | 85 |

* Estimated average count for whole of trial area.

Table 2

PCE Assessments (eggs/g soil) multiplication rates after cropping

| Treatments (kg/ha) | Trial 1 | Trial 2 | Trial 3 | Trial 4 | Trial 5 | Trial 6 | Trial 7 | Trial 8 |
|---|---|---|---|---|---|---|---|---|
| Untreated | 8.0 | 34.0 | 24.0 | 10.7 | 10.0 | 13.6 | 0.6 | 8.0 |
| Dazomet 227(S) | - | - | 4.4 | 3.0 | 1.6 | 4.5 | 0.3 | 1.7 |
| Dazomet 395(S) | - | - | 3.3 | 3.2 | 4.1 | 2.0 | 0.2 | 2.9 |
| Dazomet 227(N) | 4.0 | 20.0 | 4.2 | 4.0 | 1.4 | 1.5 | 0.2 | 1.5 |
| Dazomet 395(N) | - | - | 6.5 | 3.6 | 0.9 | 20.5 | 0.4 | 1.2 |

S = September applied
N = November applied

Table 3

Yield assessments - total yield of potatoes in tons/ac

| Treatments (kg/ha) | Trial 1 | Trial 2 | Trial 3 | Trial 4 | Trial 5 | Trial 6 | Trial 7 | Trial 8 |
|---|---|---|---|---|---|---|---|---|
| Untreated | 5.2 | 18.9 | 28.5 | 11.2 | 29.7 | 11.9 | 3.3 | 12.8 |
| Dazomet 227(S) | - | - | 33.1 | 11.4 | 32.1 | 10.9 | 6.6 | 13.7 |
| Dazomet 395(S) | - | - | 32.2 | 12.9 | 32.4 | 14.4 | 6.7 | 14.4 |
| Dazomet 227(N) | 13.0 | 25.5 | 32.2 | 14.0 | 31.6 | 14.0 | 5.5 | 16.0 |
| Dazomet 395(N) | - | - | 31.3 | 12.8 | 33.1 | 14.7 | 8.0 | 15.9 |

S = September applied

N = November applied

Other Assessments

1. Weeds

All trials were assessed for control of perennial and annual weeds.

2. Potato Haulm

Assessments were carried out on two trials for control of Rhizoctonia. Untreated plots were compared to the 395 kg/ha rate of dazomet.

3. Potato tuber

Three trials were assessed for tuber diseases pre-planting and post-harvest.

4. PCE death assessments

Assessments were carried out pre-planting of potatoes to determine the percentage kill of PCE on the treated plots using staining techniques (New Blue R) and also hatching experiments.

## DISCUSSION

PCE assessments indicated that treatment with dazomet prevented the large increase in eelworm populations which can occur after growing potatoes on infected soil.

In 1971 dazomet 224 kg/ha in Trial 1 reduced the PCE multiplication rate by half and produced an average of 7-8 tons/ac increase over the untreated plots. Trial 2 produced a similar increase in yield, although the population increase was higher. This could have been caused by the poor conditions prevailing at the time of application of the chemical, making incorporation difficult.

In 1972, PCE populations increased by an average of 3.5 x on the dazomet plots compared to 14 x on the untreated. Yield of potatoes was increased by an average of 3.5 tons/ac.

The degree of PCE control and increase in yield of potatoes varied only marginally with rate of dazomet used and time of application.

Assessments carried out to determine the percentage kill of PCE in the treated plots were unfortunately not meaningful owing to the unreliability of the methods used.

Good control (approx. 95%) of Tussilago farfara (Coltsfoot) and Agropyron repens (Couch grass) was obtained with all dazomet treatments. Autumn germinating annual weeds such as Stellaria media (Chickweed) and Matricaria spp. (Mayweeds) were also well controlled. The November applications tended to give the best overall weed control.

Assessments for potato haulm and tuber diseases showed no differences between treated and untreated plots. Unfortunately disease-free tubers were not available for planting in these trials, so differences in tuber disease levels were probably related to the disease on the seed tubers. It may be worthwhile repeating the experiment using clean stock.

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# RESULTS WITH FENAMIPHOS IN POTATOES AND VEGETABLE CROPS

B. Homeyer
Bayer AG, Leverkusen, W. Germany

**Summary** Fenamiphos is the suggested common name for ethyl 4-(methylthio)-m-tolyl isopropylphosphoroamidate, a nematicide discovered by Bayer AG. It was tested in granular and emulsifiable concentrate formulations for its suitability in controlling the nematodes *Medoidogyne incognita* on tomatoes, *Heterodera rostochiensis* and *Trichodorus* spp. on potatoes, *Ditylenchus dipsaci* on onions and *Meloidogyne hapla* on carrots.

9o-99 % control was achieved with rates of 1o-2o kg fenamiphos per ha against root nematodes and with 2.5 - 5 kg against stem nematodes. There was no significant difference in effectiveness between the granular and the e.c. formulations. Populations of potato cyst nematodes in the soil were reduced with rates down to 1o kg fenamiphos per ha, even on susceptible potato cultivars. Yield increases in tomatoes, potatoes and carrots ranged from 1o to over 1oo %.

These results suggest that fenamiphos is a highly effective nematicide which is well tolerated and can be recommended for the control of nematodes on potatoes and a number of important vegetable crops.

## INTRODUCTION

Our laboratory, glasshouse and field trials work has shown that fenamiphos is a very effective nematicide with a broad spectrum of activity, a long persistence and good crop tolerance. Our work on vegetable crops and potatoes aimed at determining optimal rates and the relative effectiveness of granular and e.c. formulations, as well as the effect of control measures on yield.

## TRIALS AND RESULTS

Trials work was done on tomatoes, potatoes, onions and carrots and details are reported as follows:

TOMATOES

Tomatoes are attacked by free-living nematodes and root knot nematodes. Under our climatic conditions damage is most severe in crops grown under glass but in warmer climates nematodes are equally important on outdoor tomatoes.

Our trials were done in large glasshouses in the Rhineland where infestations of Meloidogyne incognita were rather severe. Granular formulations containing 5 and 1o % fenamiphos were tested using DD as comparison. There were 3 replicates and the plots measured 3 x 4 metres. The layout was such that each treated plot had an untreated control alongside. The granular formulations were applied 2 1/2 weeks before planting and incorporated by rotovating; DD was injected at the same time. At harvest the plants were lifted and the number of galls which had developed on the root system were counted. The degree of effectiveness was calculated according to Abbot (1925) and Table 1 shows the results obtained.

Table 1

Effect of 5 and 1o % granular formulations of fenamiphos against Meloidogyne incognita on tomatoes

| % Effectiveness of fenamiphos | | | % Effectiveness of DD | |
|---|---|---|---|---|
| Dosage ai/ha | 5 % GR | 1o % GR | Dosage ai/ha | DD |
| 3o kg | 97.3 | 95.8 | 5oo l | 95.6 |
| 2o kg | 91.5 | 92.1 | 4oo l | 93.7 |
| 1o kg | 88.6 | 88.1 | 3oo l | 68 |
| 5 kg | 62 | 57 | 2oo l | 32 |

It is apparent that systemic nematicides like fenamiphos are effective at much lower rates than DD. The 5 % granular formulation of fenamiphos was slightly superior to the 1o % granules, probably due to a better distribution in the soil.

For economic reasons further development work was done mainly with the 1o % fenamiphos granule. Trials at our Experimental Station in Italy aimed at determining the effect of fenamiphos on the yield of tomatoes and to compare the granular and e.c. formulation of fenamiphos. Plot size was 5 x 2o metres, with 3 replicates per treatment. Granules were broadcast whilst the e.c. was applied overall by knapsack sprayer at 4oo l/ha; all formulations were incorporated into the soil by rotovating. Tomatoes were planted one week after application. The weight of mature tomatoes from the various plots was determined at picking. Biological effectiveness was assessed by counting the number of root galls and the results are expressed as per cent effectiveness calculated according to Abbot (1925) and are shown in Table 2.

Table 2

Effect of granule and e.c. formulations of fenamiphos against *Meloidogyne incognita* on tomatoes

| Dosage rate ai/ha | % Effectiveness 1o % GR | 4oo EC | Yield (untreated = 1oo) 1o % GR | 4oo EC |
|---|---|---|---|---|
| 2o kg | 96 | 93 | 145 | 151 |
| 1o kg | 9o | 88 | 129 | 13o |

It can be seen that the granular formulation was slightly more effective than the e.c. but there was little difference in yield.

A considerable number of trials with fenamiphos on tomatoes were carried out in various other countries and the positive results obtained have led to its commercial usage in some of them e.g. the USA and Australia.

POTATOES

Nematodes are of great economic importance in potatoes, where *H. rostochiensis* can cause direct damage, whilst *Trichodorus* spp. can act as a vector of virus disease. Strict quarantine regulations on an international basis emphasise the damage caused by *H. rostochiensis*. To limit its spread longer rotations are recommended in a number of countries where it is suggested that potatoes should be grown on the same land only every 3rd or 4th year. In some countries potatoes are not allowed to be grown at all on infested land. These prophylactic measures are incompatible with the need of farmers to grow potatoes for economic reasons more frequently on suitable soils. The use of effective nematicides is therefore of great practical interest, in spite of the existence of resistant cultivars. Against this background fenamiphos was tested against potato root eelworm in 1972 (Homeyer 1973).
In 1973 trials were continued using fenamiphos primarily as an emulsifiable concentrate. Two of these trials were done in the Kaarst area on light soils which are rather severely infested with *H. rostochiensis*. Treatments were replicated three times and the plot size was 5 x 2o metres. Treated and untreated plots were located side by side aiming at greater uniformity in levels of infestation and trying to overcome the inherent difficulties in the field evaluation of nematicides due to uneven infestation levels in different parts of potato fields. A 4o % e.c. of fenamiphos was sprayed overall in 6oo l water/ha and harrowed into the soil. The potatoes (cultivar Arensa) were planted 3 weeks after treatment. Assessments were carried out by:

1 Determining the number of newly formed yellow cysts on the roots.

2 Determining tuber yields.

3 Determining number of eggs and larvae per g of soil at treatment and after harvest.

The first cyst counts were carried out on 2o plants per plot after the majority of cysts in the untreated plots had turned yellow. The degree of effectiveness was calculated according to Abbot (1925) and results are given in Table 3.

Table 3

Effect of fenamiphos e.c. against *Heterodera rostochiensis*

| Dosage Rate | % Effectiveness | | |
|---|---|---|---|
| ai/ha | Kaarst I | Kaarst II | Average |
| 2o kg | 99 | 1oo | 99.5 |
| 1o kg | 98 | 99 | 98.5 |
| 5 kg | 9o | 95 | 92.5 |

It can be seen that 97 - 98 % control was achieved with the medium rate of 1o kgs ai per ha. This effect was also reflected in yields which were determined by weighing the tubers from 3o potato plants per plot. Results, relative to 1oo for untreated, are given in Table 4. The average yield in untreated plots was 27.6 t/ha.

Table 4

Yield in Relation to Untreated

| Dosage ai/ha | Kaarst I | Kaarst II | Average |
|---|---|---|---|
| 2o kg | 14o | 132 | 136 |
| 1o kg | 132 | 126 | 129 |
| 5 kg | 124 | 119 | 121.5 |

Due to the rapid rate of reproduction of *H. rostochiensis* control measures can only be considered as being successful if nematode populations do not increase after treatment, even on susceptible potato cultivars. For economic reasons it is not considered essential to aim at a complete or a very high level of reduction of nematodes in the soil particularly as the surviving population is being further reduced due to natural mortality at a rate of approximately 4o % per year.

In our trials we determined number of eggs and larvae before treatment and after harvest and the results are given in Table 5.

Table 5

Effect of fenamiphos on the population of H. rostochiensis

| Dosage rate ai/ha | Eggs and larvae/g soil | | | |
|---|---|---|---|---|
| | Kaarst I | | Kaarst II | |
| | before treatment | after harvest | before treatment | after harvest |
| 2o kg | 62 | 3o | 71 | 36 |
| 1o kg | 58 | 41 | 74 | 47 |
| 5 kg | 65 | 59 | 64 | 6o |
| Untreated | 62 | 1o9 | 69 | 112 |

Even on a susceptible potato cultivar, rates down to 1o kg ai/ha fenamiphos reduced the nematode population in the soil considerably. Whitehead et al (1973) reported similar results with fenamiphos on sandy loams.

This opens new possibilities for potato growers who are now, with the help of chemical control measures, able to grow susceptible cultivars without increasing nematode levels in the soil.

Trichodorus spp is another nematode of economic importance on potatoes. It can transmit and spread the rattle virus which causes symptoms known as "Spraing" and efforts have been made to check this disease by controlling the vectors (Cooper and Thomas 1971).

Initially after encouraging results with fenamiphos granules fenamiphos e.c. was tested in 3 trials last year. Application was made by overall spraying at 6oo l/ha one week before planting and incorporation was done by harrowing. At harvest time tubers from untreated and treated plots were assessed for symptoms of 'Spraing' disease and the results are given in Table 6.

Table 6

Effect of fenamiphos 4oo e.c. on potato 'Spraing' disease

% of potatoes infested with 'Spraing' symptoms.

| Dosage ai/ha | Trial 1 | Trial 2 | Trial 3 | Average |
|---|---|---|---|---|
| 1o kg | 3 % | 6 % | 4 % | 4.4 % |
| Untreated | 35 % | 44 % | 39 % | 39.3 % |

In view of the encouraging results obtained with 1o kg ai/ha it is plannned to do further work to determine the effectiveness of fenamiphos in reducing the incidence of 'Spraing' at lower rates.

ONIONS

Ditylenchus dipsaci is a very widespread and dangerous pest in onions and where they are grown intensively. In particular, on heavy soils, losses are considerable and control measures essential. Fenamiphos was therefore tested against this pest, both as a 1o % granule and as a 4o % e.c. Plot size was 2 x 5 m, and treatments were replicated 3 times. The granules were broadcast and incorporated by raking whilst the e.c. formulation was sprayed onto the soil surface without subsequent incorporation. The whole trials area was treated with propachlor to prevent development of weeds. Stand counts were done at monthly intervals, and affected plants were examined in the laboratory to ensure that infestation with onion fly could not lead to a misinterpretation of results. At harvest time the average level of nematode infestation in untreated plots was 23 %. Table 7 shows the degree of control obtained with fenamiphos.

Table 7

Effect of fenamiphos against Ditylenchus dipsaci on onions

| Dosage rate ai/ha | Fenamiphos 1o GR | Fenamiphos 4oo EC |
|---|---|---|
| 7.5 kg | 1oo % | 1oo % |
| 5.o kg | 99.1 % | 99.6 % |
| 2.5 kg | 97.7 % | 97.o % |

It can be seen that even low rates of 2.5 - 5 kg ai/ha gave almost complete protection against attack of D. dipsaci, with the granular and the liquid formulation performing equally well.

CARROTS

In many areas carrots are attacked by the root knot nematode, M. hapla: free-living nematodes of the genus Pratylenchus also seem to be on the increase as pests of carrots.

With the opportunity to test fenamiphos on carrots at sites near Leverkusen which were heavily infested with M. hapla a number of field trials were completed. Plot size was 5 x 1o m. and fenamiphos e.c. was applied 3 weeks before sowing to the soil surface by knapsack sprayer and incorporated by harrowing. At harvest time the roots were examined for the typical gall-like growths and from these assessments the degree of effectiveness was calculated for the various treatments. The results are given in Table 8.

Table 8

Effect of fenamiphos e.c. against Meloidogyne hapla on carrots

| Dosage rate ai/ha | % Effectiveness | |
|---|---|---|
| | Leichlingen | Reusrath |
| 2o kg | 97 % | 99 % |
| 1o kg | 95 % | 98 % |
| 5 kg | 91 % | 94 % |

The carrots from the treated plots had made much better growth and developed into good and sizeable roots, whilst the carrots from the untreated plots remained small and were very often mis-shapen. When determining yields the crop was graded into two categories - saleable and unsaleable - with the following results :

Table 9

Yields and saleable quantities of carrots after application of fenamiphos

| Dosage rate ai/ha | Yields | | Saleable Quantities | |
|---|---|---|---|---|
| | Leichlingen | Reusrath | Leichlingen | Reusrath |
| 2o kg | 21o | 23o | 88 % | 1oo % |
| 1o kg | 172 | 18o | 8o % | 88 % |
| 5 kg | 146 | 166 | 57 % | 8o % |
| Untreated | 1oo | 1oo | 7 % | 2o % |

Resumé Fenamiphos est le nom courant proposé pour ethyl 4-(méthylthio)-m-totyl isopropylphosphoroamidate, un nématocide mis au point par Bayer AG. Il fut essayé sous forme granulaire et émulsions dans la lutte contre l'anguillule de la tomate Meloidogyne incognita, les anguillules de la pomme de terre Heterodera rostochiensis et Trichodorus sp.. l'anguillule de l'onion Ditylenchus dipsaci et l'anguillule de la carotte Meloidogyne hapla. Des résultats de 9o - 99 % furent obtenus avec des concentrations de 1o - 2o kgs de fenamiphos par hectare, contre les anguillules des racines et de 2,5 - 5 kgs contre les anguillules des tiges.

Il ne faut noter aucune différence d'action importante entre les formes granulaires et les émulsions.

Le nombre de cystes de l'anguillule de la pomme de terre dans le sol fut diminué avec des concentrations de 1o kgs de fenamiphos par hectare, ceci même sur des plants de pomme de terre prédisposés à l'infestation. Les augmentations du rendement des tomates, pommes de terre et carottes variaient de 1o à plus de 1oo %.

Ces résultats montrent que le fenamiphos est un nématicide très actif, bien toléré par les cultures et il peut être recommandé dans la lutte contre l'anguillule de la pomme de terre et de bien d'autres cultures maraîcheres importantes.

The fenamiphos treatments increased yield by 5o to over 1oo %. More important, the quantities of good quality and marketable carrots were increased by 5 - 1o times.

In addition, trials with fenamiphos have also been carried out against Pratylenchus hamatus and Rotylenchus uniformis, with similar rel. positive results.

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# TRIALS ON THE CHEMICAL CONTROL OF THE POTATO CYST EELWORM IN THE YORKS AND LANCS REGION

J Morgan Jones

Agricultural Development and Advisory Service, Lawnswood, Leeds

Summary A series of trials was started in 1972 to investigate the value of soil treatments with sterilants and nematicides against the Potato Cyst Eelworm. Results from five completed in 1972 showed that dazomet at 200 and 350 lb/ac and dichloropropene at 24 gal/ac gave good increases in yields of potatoes on mineral soils but not on peat. Dazomet at both rates also reduced substantially the rate of eelworm multiplication as compared with untreated plots when the land was cropped. Fenamiphos, as used in these trials was less successful.

Because of high in-put costs and the substantial additional costs of treatment, control of the Potato Cyst Eelworm by chemical means is likely to be economically rewarding only on the more productive potato land and where systems of management and husbandry are adequate to exploit its potential.

Resume Une série d'essais fut commencée en 1972 pour évaluer la valeur de traitements du sol, avec des sterilisants et nématicides contre les cystes de l'Anguillule de la pomme de terre. Les résultats obtenus après cinq essais terminés en 1972 indiquèrent que le dazomet, à des concentrations de 200 et 350 livres/ac et le dichloropropène, à une concentration de 25 gal/ac, augmentèrent le rendement des pommes de terre sur sols minéraux mais non sur sols tourbeux. Dazomet, aux deux concentrations données, réduisit aussi la multiplication de l'Anguillule, en comparison avec les terrains non traités, ceci après récolte.

A cause des frais de production éléves at des coûts additionels de traitement, la lutte contre l'anguillule de la pomme de terre ne sera interessante sur le plan financier que sur les terres les plus productives et si le mode d'exploitation et l'agriculture utilisés permettent son developpement.

## INTRODUCTION

It has been known for many years that chemical sterilisation of soils infested with the Potato Cyst Nematode (Heterodora rostochiensis and H. pallida) can lead to large increases in the yields of potatoes. But the high costs of sterilants coupled with the fact that post-cropping eelworm numbers were often as high, if not higher, after treatment as without it (and the consequent need to use sterilants before each succeeding crop of potatoes) have, in the past, made them commercially unattractive. Nowadays higher yields, through the use of new varieties, more fertilizer, and improved husbandry techniques, together with better prices per ton have greatly increased gross outputs from potatoes. At the same time more sophisticated machines have been developed for incoporating chemicals as liquids, powders and granules in the soil. Their use can increase the effectiveness of chemicals by mixing them more intimately with the soil and at the same time reduce the costs of their application. New chemicals, more specifically nematicidal than the old, have also been developed during recent years and workers at Rothamsted (Whitehead et al, 1973 a, 1973 b) have shown that both these and some of the old at appropriate rates and using modern application techniques can arrest the rate of build-up of the eelworm when potatoes are grown and, under the best conditions, even reduce their numbers to below their pre-cropping levels.

Farmers are becoming aware of these new developments and are seeking guidance about the practicability of using chemicals for the control of PCN under their own conditions. It was decided therefore to initiate a series of trials in 1971 in the Yorks and Lancs Region to re-appraise the value, particularly from the economic standpoint, of promising materials on a variety of soil types and under as wide a range of eelworm populations as possible. Five trials were completed in 1972 and six more are being done this year. Results from these are not available at the time of writing.

## MATERIALS AND METHODS

Details of materials, rates of application, soil types and eelworm levels are given in Tables 1-4. Individual plots measured 20 yard lengths of 7-9 drilles at 28 in. or 30 in. spacings and replication in each case was fourfold. All applications were made by means of commercially-appropriate equipment, dichloropropene by contractor-type injectors and dazomet and fenamiphos by Horstine Farmery applicators mounted at the front of the tractor, the materials being incorporated to a depth of about 8 in. in the same operation by means of rear-mounted rotavators. All three materials were applied in this fashion, the dazomet at two rates, in late October and early November 1971. Additionally, fenamiphos was applied in narrow bands, again by means of Horstine Farmery equipment, in the drill at planting in the spring of 1972. It has since been learnt that neither of the methods employed, overall autumn incorporation or spring furrow placement, is likely to be the most effective means of using nematicides like fenamiphos. Because of relatively short persistance and its mode of action on eelworms overall spring applications are probably better for this type of chemical. Fifteen yard lengths of the centre three drills in each plot were harvested in September/October 1972 and graded over a 1½ in. riddle. Eelworm counts were made separately for each plot before treatment and after harvest.

## RESULTS

The results are given in Tables 1-3. Large increases in yields were given by the sterilants on three of the mineral soil sites, smaller ones on the fourth and, with the exception of dazomet at the high rate, none on the peat. Fenamiphos was less effective than the sterilants but as already pointed out it probably was not used to the best advantage in these trials. The autumn application in each case proved more effective than the spring, but this is thought to have been due more to the method of application than to the time of treatment. Apart from the poor performance on past, there was no clear relationship between response and soil types or pre-cropping eelworm levels. Tables 2 and 3 show that, with the exception of site 3 where almost complete failures of three of the four control plots limited eelworm build-ups, dazomet at both rates consistently and significantly reduced the rates of eelworm build-up and gave substantially lower counts after cropping than on control plots. This was true of even the peat site where no yield responses were obtained.

## DISCUSSION

An attempt is made in Table 4 to examine the economic significance of treatment. At present-day costs of production it is estimated that an average gross output of about £200 per acre, equivalent to yields of about 12 tons per acre of saleable ware at the 1972 guaranteed price is necessary to give the farmer a modest profit on his potato crop. Assuming costs of treatment of £30-£40 per acre, yields in excess of 14 tons per acre must be obtainable before the use of nematicides becomes attractive, when viewed in the context of the overall costs of production. This sort of analysis (Table 4) shows that although costs of treatment were fairly regularly recovered (13 out of 17 treatment/site situations) it was only at Site 1 that nematicides made any real contribution to the overall profitability of the crop. No treatment except the high rate of dazomet on Site 3 changed loss situations on untreated plots (Sites 2, 3 and 5) into ones that were profitable overall. High dazomet and dichloropropene on Site 4 decreased profits and all treatments increased the loss on Site 5 because their costs were not recouped. Further trials and more cost/benefit analyses of this nature are clearly desirable before we can confidently advise growers on the situations where the use of chemicals against PCN can be economically worthwhile. Because of the high costs involved in producing potatoes, it seems likely that good returns will only be possible on land with a high yield potential and where techniques of management and husbandry are adequate to achieve that potential.

## Acknowledgements

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Table 1

Yields of Ware (Tons/Ac Over 1½ in. Riddle)

| Site | Eelworm eggs/gm Range/plot | Control | D/L | D/H | Di | F/A | F/S | SE | LSD |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 9-55 | 12.0 | 22.0 | - | 21.3 | 17.2 | 16.6 | 0.9 | 2.7 |
| 2 | 15-69 | 6.4 | 11.5 | - | 11.7 | 8.8 | 6.0 | 1.3 | 3.9 |
| 3 | 5-328 | 4.4 | 11.0 | 14.7 | 10.3 | 10.0 | 6.1 | 1.1 | 3.2 |
| 4 | 24-63 | 13.1 | 15.5 | 16.0 | 14.2 | - | - | 0.7 | 2.4 |
| 5 | 13-317 | 10.3 | 9.8 | 11.9 | 10.1 | - | - | 0.8 | NS |

| | | |
|---|---|---|
| D/L | Dazomet | 200 lbs/ac autumn |
| D/H | " | 350 lbs/ac " |
| Di | Dichloropropene | 24 gal/ac " |
| F/A | Fenamiphos | 5 lbs ai/ac " - overall |
| F/S | " | 5 lbs ai/ac spring - in furrow |

Table 2

Post Cropping Eelworm Populations - Eggs/gm

| Site | Control | D/L | D/H | Di | E/A | E/S | SE | LSD |
|---|---|---|---|---|---|---|---|---|
| 1 | 345 | 119 | - | 282 | 365 | 330 | 48 | 151 |
| 2 | 284 | 105 | - | 236 | 171 | 199 | 31 | 99 |
| 3 | 290 | 358 | 290 | 278 | 243 | 291 | 37 | NS |
| 4 | 548 | 169 | 141 | 553 | - | - | 40 | 132 |
| 5 | 664 | 308 | 227 | 668 | - | - | 102 | 326 |

Table 3

Eelworm Build-ups $\frac{\text{(Post-cropping Counts)}}{\text{(Pre-treatment Counts)}}$

| Site | Control | D/L | D/H | Di | F/A | F/S |
|---|---|---|---|---|---|---|
| 1 | 19.5 | 5.9 | - | 17.2 | 17.6 | 17.2 |
| 2 | 7.4 | 5.0 | - | 7.7 | 5.8 | 6.2 |
| 3 | 4.4 | 2.9 | 3.4 | 12.1 | 3.5 | 2.5 |
| 4 | 15.3 | 3.9 | 4.1 | 13.5 | - | - |
| 5 | 4.9 | 2.1 | 2.1 | 16.4 | - | - |
| Means | 10.3 | 4.0 | - | 13.4 | - | - |

## Table 4

## Profitability of Nematicide Usage

| Site | Soil Type | Control | D/L | D/H | Di | F/A | F/S |
|---|---|---|---|---|---|---|---|
| 1 | Sandy silt | [P] | [PC5] | - | [PC5] | [PC3] | [PC2] |
| 2 | Blowing sand | P | PC3 | - | PC3 | PC1 | PC0 |
| 3 | Sandy loam | P | PC3 | [PC3] | PC3 | PC3 | PC1 |
| 4 | Sandy loam | [P] | [PC1] | [PC0] | [PC0] | - | - |
| 5 | Peat | P | PC0 | PC0 | PC0 | - | - |

[P] = profitable overall. P = Not so.

C Cost of nematicide at £35 pa
C0 " " " not recovered
C1-5 " " " recovered 1-5 times

Proceedings 7th British Insecticide and Fungicide Conference (1973)

# VIRUSES LATENT IN HOP (HUMULUS LUPULUS L.) AND TECHNIQUES FOR OBTAINING VIRUS-FREE CLONES

A.N. Adams

East Malling Research Station, Maidstone, Kent.

Summary All plants of most English commercial hop cultivars are probably infected with prunus necrotic ringspot virus (NRSV), hop mosaic virus (HMV) and hop latent virus (HLV). NRSV can be eliminated by heat treatment at 35°C for 7 days followed by culture of 1-5 cm excised shoot tips or by 3 days therapy followed by culture of 5 mm tips. Meristem culture was used for the elimination of HMV and HLV; it took 4-6 weeks for 66% of the 0.3-0.8 mm explants to grow into rooted plants, and 74% of these were free from both viruses. A combination of these techniques will now be applied routinely to the plant breeders' selections before final trials so that all future varieties can be released in virus-free condition.

Re-infection with NRSV and HLV is slow in East Anglia where 'A-plus' stocks are raised. Although spread in the Weald of Kent is greater, results with Northern Brewer have indicated the improved yield potential of virus-free plants.

## INTRODUCTION

All but the most recently introduced English hop cultivars are infected with two viruses that cause no symptoms; prunus necrotic ringspot virus (NRSV) and hop latent virus (HLV). A third virus, hop mosaic (HMV), is latent in tolerant cultivars; such cultivars comprise over 80% of the country's acreage. All plants tested for latent infection with these viruses have contained all three and therapy is therefore the only means of obtaining virus-free plants.

There are many examples of virus-free plants outyielding apparently healthy plants infected with viruses. For example, King Edward potato plants freed from paracrinkle virus by meristem culture look no different from infected plants but produce 10% more crop (Kassanis, 1961); virus-free pears grow more vigourously and produce over 30% more fruit in the first three harvests than symptomless trees infected with the commonly occurring vein yellows and mosaic viruses (Cropley and Posnette, 1973).

Virus-free hop plants have not been available in the past for comparison with commercial stocks but recently at Wye College, Neve (1972) found that the hop cultivar Northern Brewer, freed from HMV and NRSV at East Malling (Vine and Jones, 1969), yielded nearly 30% more alpha-acid per acre than the best commercial clones. Recent trends in brewing have made the alpha-acid content of hops their most important market quality and the yield increment obtained by freeing plants from two of the three latent viruses has indicated the high potential of totally virus-free hops.

This paper outlines the techniques developed for freeing plants from all three latent viruses and discusses the introduction of virus-free material to the industry.

## Therapy techniques

Early work at East Malling on heat therapy of hop was unsuccessful, mainly due to the difficulty of keeping plants alive at high temperatures (Harris, 1953; Ormerod, Paine, Legg, unpublished data). However, Schmidt (1967 and unpublished data) at Aschersleben, East Germany, kept plants at 37°C for 3-4 weeks and then raised 5-10 cm shoot tip cuttings from them. Ten per cent of these plants werefreed from NRSV but no data are available for HMV and HLV.

Vine and Jones (1969) grew plants at 35°C for 2-4 weeks before excising and culturing shoot tips 1-3 mm long. Seventy out of 73 such plants were free from NRSV; 72 were free from HMV but all were still infected with HLV. In my work two techniques were investigated separately:(a) heat therapy followed by the culture of shoot tips 5-50 mm long, (b) culture of 'meristems' from unheated source plants.

### Heat Therapy

Plants for heat therapy were grown in a cabinet at 35°C with a 16 h day-length by artificial illumination and shoot tips were removed at intervals for culture. Tips longer than 1 cm were raised in peat compost in a plastic propagation box; shorter ones were grown in test tubes under sterile conditions with a simple nutrient solution.

When shoot tips of 1-5 cm length were detached from motherplants receiving heat treatment for 10-18 days and grown on, all the resulting 29 plants were free from NRSV and 13 were also free from HMV. Two further experiments showed that NRSV could be eliminated from the variety Fuggle after only 3 days heat treatment if shoot tips 5 mm long were cultured; 10 out of 12 plants raised in this way were free from NRSV. All 15 plants cultured after 7 days therapy were healthy.

Plants from 5 mm propagules were not tested for HMV but it is clear that a few days of heat therapy can eliminate NRSV from the terminal 1-5 cm of shoot. Tips of this size are easily propagated. Virus tests are reliably made by sap inoculation to cucumber cotyledons on which sap from infected plants causes local chlorotic lesions within one week followed in severe cases by stem necrosis and death.

Although this technique was simple and rapid for NRSV elimination, meristem culture was necessary to remove HMV and HLV.

### Meristem culture

None of the plants raised from 1-3 mm shoot tips by Vine and Jones (1969) was free from HLV although the source plants were heat treated. It has frequently been found that reducing the size of the explant increases the proportion of virus-free plants (Stone, 1968; Mellor and Stace-Smith, 1970); an attempt was therefore made to grow hop plants in vitro from meristem tips 0.3-0.8 mm long containing two or three pairs of leaf primordia.

Meristems were dissected in a sterile laminar air-flow cabinet and each placed in a tube of sterile culture medium on a filter paper bridge. After 2-4 weeks, when 2-20 mm shoots had grown, these were transferred to a second culture solution solidified with 0.6% agar.

Roots formed within 10-50 days and plantlets were sturdy enough to pot in compost 1-2 weeks later. Growth of explants varied according to the condition of the source plants but under optimal conditions 66% grew into rooted plants in 4-6 weeks.

Meristem plants were tested for HMV and HLV 3-6 months after excision when they had grown to 10-50 cm. Both viruses are 650 nm semi-flexuous rods and were detected by electron microscopy. Particles were readily found in infected plants but extended searches rarely revealed virus-like particles if they were not found quickly, indicating that the test was reliable. The results (Table 1) show that, unlike NRSV, HLV and HMV had been eliminated from most plants by meristem culture.

Table 1.

Occurrence of NRSV and 650 nm rods in hop plants after meristem culture

| Cv. | Viruses before culture | Viruses after culture | + | - |
|---|---|---|---|---|
| Bramling | NRSV, HLV | NRSV | 56 | 1 |
| | | Rods | 12 | 30 |
| Northdown | HMV | Rods | 1 | 5 |
| Challenger | HMV | Rods | 0 | 2 |

Virus resurgence can occur in plants up to one year after apparent elimination by meristem culture (Hollings and Stone, 1968). Retests of hop plants up to one year after excision, however, confirmed the negative results obtained initially.

The reliability of the two techniques, heat therapy and meristem culture, should enable healthy plants to be derived from infected ones in one year with a further year to confirm their freedom from virus.

## INTRODUCTION OF VIRUS-FREE MATERIAL TO THE INDUSTRY

### Propagation

The highest quality stocks now available are raised in East Anglia in isolation from commercial crops which are grown mainly in Kent and the West Midlands. Wye College supplies the propagators with material that can be used as parent stock for 10 years before renewal. Such plants and their progeny are inspected twice during the growing season by the Ministry of Agriculture and are given an 'A-plus' certificate provided they reach the required standard of health.

All 'A-plus' clones, apart from NRSV-free selections of the new cultivars Wye Northdown, Wye Challenger and Wye Target, are infected with all three latent viruses.

Some modification of the 'A-plus' scheme is obviously necessary if the virus-free state of meristem cultured and heat treated material is to be preserved.

The risks of re-infection in East Anglia must be reduced by isolation from infected plants but two main problems arise: lack of information on the spread of these viruses and the difficulty of detecting infection in the field.

There is no information on the spread of HLV, but in East Anglia symptoms of HMV have never been seen in mosaic sensitive cultivars which are isolated by a distance of at least 1 mile from mosaic-carrying hops. Tests by Thresh and Ormerod (unpublished) in East Anglia on the spread of NRSV into plants 50-100 yd from the nearest source have detected only one infection in annual samples of 100 plants taken over a period of 4 years.

We are now changing from infected to healthy planting material and all stocks in East Anglia should be replaced within a few years by virus-free plants. The techniques described above will allow promising new clones from the breeding programme at Wye College to be tested as a routine and if necessary treated by meristem culture or heat therapy, thus ensuring that new cultivars start virus-free. Present knowledge indicates that re-infection with NRSV and HMV is improbable in East Anglia if all infected hop plants are first removed.

## Re-infection in hop gardens

Eventual re-infection with HMV and NRSV appears inevitable in hop growing areas but the rate differs greatly between plantings. From 17-70% of hop plants grown close to sources of infection became re-infected with NRSV in 3 years at Wye College and East Malling, but at two other sites there was little infection after one or two years (Thresh and Ormerod, unpublished). Although pollen transmission occurs in other crops (Gilmer and Way, 1963; Fry and Wood, 1971) the virus must have a vector that feeds on hops since spread to male plants and deblossomed females has been recorded (Thresh and Ormerod, unpublished).

Hop mosaic spreads rapidly at some locations. Most of the breeding material planted becomes infected at Wye where Bock (1967) exposed seedlings for 24 h periods during the period of aphid migration; on one day 10 out of 50 plants became infected. In other areas little spread occurs despite the proximity of mosaic-sensitive cultivars to tolerant ones (Keyworth, 1946). The vector is thought to be an aphid but the virus has been transmitted only occasionally in experiments (Paine and Legg, 1953; Bock, 1967). Several viruses with similar particles are aphid transmitted in the non-persistent manner and the spread of such viruses into a crop is often greatly reduced by isolation of 100 yards or more from the nearest source of infection. Spread into large plantings would be slower than into small groups of plants surrounded by infected plants.

Virus-free plants will soon be available to propagators and growers in place of A-plus material and the evidence so far suggests that they can be propagated and supplied to growers in that condition. Even if the rate of spread into plantations were high, profitable increments in yield should be obtained in the period between planting and re-infection.

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# CONTROL OF POWDERY MILDEW OF HOP (Sphaerotheca humuli) WITH THE SYSTEMIC FUNGICIDE PYRAZOPHOS

S. J. B. Hay
Hoechst U.K. Ltd., Agricultural Department, Hoechst House, Hounslow, Middlesex

Summary Replicated field trials in the U.K. have shown pyrazophos to be highly effective against the powdery mildew of hop (Sphaerotheca humuli).

Foliar sprays of 0.023 - 0.03% applied every 10-14 days between bine training and harvest gave outstanding control of leaf infections and significantly reduced cone disease. More frequent spraying at lower rates gave only marginally better results. The inclusion of pyrazophos with the April 'spike-sprays' also prevented the early establishment of mould in problem gardens.

Hops treated with pyrazophos produced uniformly larger and heavier cones than standard and large increases in crop yield were recorded.

Pyrazophos markedly depressed populations of the damson-hop aphid (Phorodon humuli) on foliage and in cones, thereby supplementing the standard insecticide programmes.

This work has been verified during 1972 and 1973 by the extensive commercial use of a 30% emulsion at rates up to 16 fl. oz/ac (1.12 l/ha).

Résumé Des essais en champs répétés, effectués au Royaume-Uni ont révélé que le pyrazophos est très efficace contre l'oidium du houblon (Sphaerotheca humuli).

Des pulvérisations sur les feuilles à raison de 0.023 à 0.03% et à intervalles de 10 à 14 jours, entre l'accolage et la récolte, ont permis de maîtriser tres efficacement l'infection des feuilles et de réduire considérablement les maladies des cônes. Des pulvérisations plus fréquentes en quantités inférieures n'ont que faiblement amélioré les résultats. L'emploi du pyrazophos, en avril, dans le cadre du traitement des pousses a permis d'éviter l'infection prématurée par les moisissures dans les houblonnières 'problématiques'.

Le houblon traité au pyrazophos formait régulièrement des cônes plus longs et plus lourds que la normale et donnait à la récolte des rendements nettement supérieurs.

Le pyrazophos réduisait considérablement les colonies de pucerons du houblon (Phorodon humuli) sur les feuilles et les cônes, apportant ainsi un complément aux programmes usuels de lutte contre les insectes.

Cette étude a été étayée durant les années 1972 et 1973 par l'emploi à grande échelle d'une émulsion à 30%, en quantités allant jusqu'à 1.12 l par ha.

## INTRODUCTION

Pyrazophos is the common name proposed to BSI and ISO for 6-ethoxycarbonyl-5-methylpyrazolo (1,5,a) pyrimidin-2-yl diethyl phosphorothionate, a systemic fungicide active against powdery mildews (Smit, 1969; Hay, 1971).

The powdery mildew or mould of hop (Sphaerotheca humuli) has over a decade become progressively severe and widespread in the U.K. and most cultivars are now subject to infection. The high alpha-acid Northern Brewer, Wye Northdown and the wilt tolerant Bramling Cross are particularly susceptible and total loss of crop has been frequently recorded, even where intensive dinocap-sulphur spray programmes have been employed.

Field trials were therefore initiated to investigate the effects of pyrazophos on the disease.

## METHOD AND MATERIALS

Trials were laid down in areas of the major hop cultivars in the South-East and West Midlands of England and were of randomised block design with plots of 50-60 hills replicated five times.

Pyrazophos and dinocap (as 30% w/v and 50% w/v emulsions respectively) were applied to run-off on given dates. Propineb and endosulfan were generally used as maintenance treatments.

Disease incidence was expressed as the percentage infected leaves on lateral shoots calculated as a mean of 40 shoots per plot. In the 1972 trials a visual scale was used to classify leaves according to area covered by mycelia. Cone disease was expressed as the percentage by number showing any degree of infection.

Aphid populations were assessed by recording the number of alatae and apterae (all stages) on the growing points and first three expanded leaves of bines selected at random within each plot.

## RESULTS

### 1971

In Kent and Hereford two trials were laid down on established Northern Brewer hops to compare the effects of several rates of pyrazophos with those of standard dinocap-sulphur sprays. Mould was present at both sites prior to spraying; at Hereford 19% of leaves were infected.

Results obtained during the season are presented overleaf.

Table 1

Effect of several rates of pyrazophos on foliage and cone mould in hops c.v. Northern Brewer

Site: Goudhurst, Kent

| Date of Assessment | Percentage infected leaves Treatment % Pyrazophos 0.008 | 0.015 | 0.023 | 0.030 | Dinocap 0.025 | Standard Error (P=0.05) ± | Application Dates |
|---|---|---|---|---|---|---|---|
| 15/7 | 5.0 | 1.6 | 1.7 | 0.0 | 6.7 | 3.21 | 10/5 25/5 |
| 21/7 | 5.7 | 2.7 | 2.9 | 1.9 | 8.7 | 1.62 | 12/6 20/6 |
| 29/7 | 9.3 | 10.7 | 1.3 | 0.0 | 10.7 | 2.90 | 1/7 |
| 11/8 | 14.9 | 12.6 | 5.0 | 2.9 | 18.2 | 1.83 | 15/7 |
| % infected cones | 23.2 | 21.3 | 13.1 | 5.7 | 26.5 | 3.18 | |

Table 2

Effect of several rates of pyrazophos on foliage and cone mould in hops c.v. Northern Brewer

Site: Bosbury, Hereford

| Date of Assessment | Percentage infected leaves *Treatment % Pyrazophos 0.008 | 0.015 | 0.023 | 0.030 | Dinocap 0.025 | Standard Error (P=0.05) ± | Application Dates |
|---|---|---|---|---|---|---|---|
| 12/7 | 28.3 | 28.0 | 20.0 | 23.3 | 55.0 | 8.44 | 1/6 14/6 |
| 27/7 | — | 36.7 | 30.0 | 33.3 | 66.7 | 10.42 | 20/6 11/7 |
| 9/8 | 44.0 | 39.5 | 27.5 | 30.2 | 72.4 | 6.11 | 17/7 |
| % infected cones | 31.8 | 22.2 | 14.7 | 13.0 | 43.3 | — | |

*Surrounding area sprayed with dinocap 0.025% + sulphur 0.50% at 10 day intervals from 28th May. Selected plots had 47.5, 60.0 and 69.0% infected leaves on respective assessment dates.

Despite the high infection pressure at both sites and the delay in applying treatments at Hereford, pyrazophos gave excellent control of leaf infections. Data are misleading however since the degree of infection of given leaves was noticeably lower in the pyrazophos plots.

At harvest the economics of control were clearly demonstrated with good correlation between rate of use of pyrazophos and cone infection. These cones also contained few aphids (Phorodon humuli) confirming earlier observations (Table 3) that pyrazophos had suppressed field populations of this pest.

Table 3

Effect of pyrazophos on populations of Phorodon humuli

Site: Goudhurst, Kent

| Assessment Date | | Treatment % | | | |
|---|---|---|---|---|---|
| | | Pyrazophos 0.03 | | Dinocap 0.025 | |
| | | Alatae | Apterae | Alatae | Apterae |
| 16/6 (3 sprays) | GP | 27 | 0 | 13 | 7 |
| | ML | 33 | 40 | 33 | 67 |
| 5/7 (5 sprays) | GP | 17 | 0 | 25 | 6 |
| | ML | 222 | 8 | 378 | 43 |
| 19/7 (6 sprays) | GP | 2 | 0 | 19 | 3 |
| | ML | 112 | 6 | 340 | 47 |

GP = 100 growth points

ML = 100 mature leaves

No phytotoxicity was recorded with any treatment and natural senescence of upper foliage was delayed on the pyrazophos plots.

## 1972

### Full season trials

In Kent, Sussex and Hereford trials were laid down on a range of cultivars to evaluate spray programmes in which the rate and frequency of pyrazophos applications were varied. Dinocap was again included at all sites and treatments were applied between the third week in May and harvest.

Characteristic results from 4 trials are given overleaf:-

## Table 4

**Effects of rate of pyrazophos and spray interval on foliage and cone mould in hops c.v. Fuggle**

Site: Northiam, Sussex

| Date of Assessment | Leaf Area Infected (%) | Percentage leaves in each infection grade – Treatment and spray interval: Pyrazophos 0.011% 7 days | Pyrazophos 0.023% 14 days | Pyrazophos 0.030% 21 days | Dinocap 0.025% 7 days | Standard Error (P=0.05) ± |
|---|---|---|---|---|---|---|
| 15/6 | 0.0 | 100 | 99 | 98 | 95 | 3.1 |
| | 0.25 | 0 | 1 | 2 | 5 | - |
| 26/7 | 0.0 | 100 | 100 | 97 | 86 | 7.4 |
| | 0.25 | 0 | 0 | 2 | 10 | - |
| | 1.0 | 0 | 0 | 1 | 4 | - |
| 8/9 | 0.0 | 99 | 99 | 94 | 80 | 2.1 |
| | 0.25 | 1 | 1 | 4 | 14 | - |
| | 1.0 | 0 | 0 | 2 | 6 | |
| % diseased cones | | 0.9 | 1.4 | 2.5 | 4.2 | 1.00 |
| mean wt/fresh cone (g) | | 0.64 | 0.61 | 0.65 | 0.59 | 0.03 |
| colour of cones (1-9) 9 = excellent | | 8.7 | 8.7 | 8.5 | 7.8 | |

## Table 5

**Effects of rate of pyrazophos and spray interval on foliage and cone mould in hops (first cropping year) c.v. Northern Brewer**

Site: Burghill, Hereford

| Type of Assessment | | Treatment and spray interval: Pyrazophos 0.015% 7 days | Pyrazophos 0.030% 14 days | Dinocap 0.025% 7 days | Nil | Standard Error (P=0.05) ± |
|---|---|---|---|---|---|---|
| % infected leaves | 29/6 | 0.0 | 0.0 | 0.6 | 1.2 | 0.81 |
| | 1/8 | 0.0 | 0.0 | 2.8 | 5.1 | 0.67 |
| % diseased cones | | 0.2 | 0.4 | 3.0 | 3.7 | 1.07 |
| mean wt/fresh cone (g) | | 0.64 | 0.64 | 0.58 | 0.57 | 0.031 |
| colour of cones (1-9) 9 = excellent | | 8.7 | 8.7 | 7.7 | 6.7 | - |

Table 6

Effects of rate of pyrazophos and spray interval on foliage and cone mould in hops c.v. Bramling Cross (OT/48)

Site: Brenchley, Kent

| Date of Assessment | Leaf Area Infected (%) | Percentage leaves in each infection grade<br>Treatment and spray interval<br>Pyrazophos<br>0.015%<br>7 days | <br><br>Pyrazophos<br>0.03%<br>14 days | <br><br>Dinocap<br>0.025%<br>7 days | Standard Error (P=0.05) ± |
|---|---|---|---|---|---|
| 10/7 | 0.0 | 87 | 81 | 74 | 6.74 |
| | 0.25 | 13 | 17 | 18 | - |
| | >1.0 | 0 | 3 | 8 | - |
| 26/7 | 0.0 | 90 | 78 | 58 | 14.6 |
| | 0.25 | 10 | 19 | 33 | - |
| | >1.0 | 0 | 3 | 9 | - |
| % diseased cones | | 3.6 | 4.2 | 11.1 | 2.96 |
| mean wt/fresh cones (g) | | 0.68 | 0.69 | 0.61 | 0.04 |
| colour of cones (1-9) 9 = excellent | | 8.8 | 8.8 | 6.7 | - |

Table 7

Effects of rate of pyrazophos and spray interval on foliage mould of hops c.v. Northern Brewer

Site: Ledbury, Hereford

| Date of Assessment | Leaf Area Infected (%) | Percentage leaves in each infection grade<br>Treatment and spray interval<br>Pyrazophos<br>0.015%<br>7 days | <br><br>Pyrazophos<br>0.03%<br>14 days | <br><br>Dinocap<br>0.025%<br>7 days | Standard Error (P=0.05) ± |
|---|---|---|---|---|---|
| 15/6 | 0.0 | 70 | 55 | 55 | 13.9 |
| | 0.25 | 27 | 35 | 42 | - |
| | >1.0 | 4 | 10 | 24 | - |
| 11/7 | 0.0 | 92 | 75 | 27 | 4.6 |
| | 0.25 | 8 | 20 | 40 | - |
| | >1.0 | 0 | 5 | 33 | - |
| 2/8 | 0.0 | 92 | 82 | 24 | 11.2 |
| | 0.25 | 5 | 15 | 36 | - |
| | 1.0 | 3 | 2 | 25 | - |
| | >5.0 | 0 | 1 | 16 | - |

Best results were obtained with the 7-day pyrazophos programmes, but these were not significantly better than the 14-day sprays. On the less susceptible Fuggle hops 0.03% pyrazophos every 21 days gave excellent control of mould on foliage but some additional cone infection was incurred. In all cases dinocap gave inadequate control with severe infection of many leaves and cones.

Cones from pyrazophos treated hops were approximately 10% heavier than standard before and after drying. No specific records were made of size but they were visually larger, particularly on distal areas of laterals, and were of much better colour.

At respective sites the 14-day pyrazophos treatments gave 6, 26, 2 and 12% more crop than comparative dinocap areas.

As in earlier trials records of aphid infestation showed reductions of 30-70% on foliage and almost complete absence from cones. This confirms independent reports (anon. 1972a) that (Phorodon humuli) is moderately susceptible to this phosphoric ester.

No phytotoxicity was incurred in any of the trials described or in associated tests where 0.06% pyrazophos was applied at weekly intervals. Some chlorosis has been noted on slow growing plants under stress caused by adverse weather conditions, poor nutrient status or heavy infection of arabis mosiac virus. The symptoms, mainly confined to older leaves below the banding-in string, had no apparent effect on the subsequent growth or yield, but tests showed they could be accentuated by the use of pyrazophos with other systemic organophosphates.

Early season trials

In a number of gardens with a history of severe primary mould, pyrazophos was included with the April 'spike-sprays' [the initial sprays for control of hop downy mildew (Pseudoperonospora humuli)] in an attempt to prevent the establishment of the disease prior to bine training.

Mixed with streptomycin or propineb, pyrazophos was applied as overhead sprays of 0.03% (using 25 gal/acre, 281 l/ha) in the first and third weeks of April.

Results at three sites assessed in mid-May clearly showed the usefulness of this technique.

Table 8

Effects of pyrazophos on the incidence of primary mould

| Site | Cultivar | Percentage leaves with no infection a | b | c | Standard Error (P=0.05) ± |
|---|---|---|---|---|---|
| Ledbury, Hereford | Northern Brewer | 100 | 99 | 83 | 2.7 |
| Brenchley, Kent | " | 100 | 100 | 80 | 0.4 |
| Brenchley, Kent | Bramling Cross (OT/48) | 100 | 100 | 96 | 2.2 |

a) Pyrazophos included with both spike-sprays

b) Pyrazophos included with second spike-spray only

c) Untreated with pyrazophos

## DISCUSSION

These experiments have shown that pyrazophos, used at rates up to 0.03% or 4.8 oz/ac (0.34 kg/ha) in a standard spray programme, gave economic control of hop mould and was much more effective than standard treatments. The further improvements in control resulting from the more frequent lower rate sprays would, under normal circumstances, be off-set by the additional cost of application. However this technique, together with that of using pyrazophos for control of primary mould pre-bine training, may be of value in areas with high innoculum potential.

The increases in crop weight noted in these trials and elsewhere (anon 1972b) require further investigation since they cannot be wholly attributed to lower levels of cone infection.

The suppressant effects of pyrazophos on field populations of the damson-hop aphid are a useful bonus since this pest continues to present serious problems throughout the hop growing areas.

## Acknowledgements

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# INSECTICIDES FOR THE CONTROL OF DAMSON-HOP APHID (Phorodon humuli)

P.W. Carden

Agricultural Development and Advisory Service, Olantigh Road,
Wye, Ashford, Kent TN25 5EL

Summary Comparisons of programmes of spray materials applied at manufacturers' recommended rates in 100 gal/ac showed that methidathion, methomyl, omethoate and methamidophos gave similar satisfactory control of damson-hop aphid.

In three years' trials mephosfolan soil drench at 1.0 g a.i./hill gave protection against the aphid for up to five weeks. 0.75 g a.i./hill was not quite so effective and 0.5 g/hill was not satisfactory.

Application of mephosfolan soil drenches in late May-mid June was more effective than application in July.

A single trial suggested that more mephosfolan enters the hop plant through the base of the bine than through the crown and roots.

Control of aphids was better when a mephosfolan soil drench was applied in 4 fl.oz/hill than when the volume of water was increased.

## INTRODUCTION

In the late 1960's field populations of damson-hop aphid in south-east England developed resistance to most of the organophosphorus insecticides in use as sprays at that time, including demeton-S-methyl. Screening tests carried out by East Malling Research Station (Anon 1970; Dicker, G.H.L. 1971 and 1972), ADAS at Wye and Evesham (unpublished) and insecticide manufacturers, showed that several organophosphorus and carbamate compounds not previously used on hops would control the aphid. The results of comparisons of five of these materials applied with a commercial sprayer are reported below.

Field experience in 1969-1972 suggested that the aphid was also developing resistance to dimefox which was the standard material used as a soil drench. The results are given of trials investigating the use of mephosfolan (proposed common name for 2-(diethoxyphosphinylimino)-4-methyl-1, 3-dithiolane) as a possible replacement for dimefox.

## METHODS AND MATERIALS

### Sprays

In 1971 and 1972 programmes of promising materials (Table 1) were applied at makers' recommended rates with a commercial sprayer (Victair Senior). Two randomised blocks of single row plots of cvs. Fuggle, Hallertau and Saaz in a Wye College hop garden were sprayed at 100 gal/ac. To avoid spray drift on the plots, two guard rows between each plot received only soil drenches.

Table 1

Spraying trials: materials and rates of application

| | Rate/100 gal/ac/application 1971 | 1972 |
|---|---|---|
| Endosulfan 35% e.c. | 24 fl.oz | 24 fl.oz |
| Methamidophos* 50% e.c. | 24 fl.oz | - |
| Methidathion 40% e.c. | 24 fl.oz | 3 applications 18 fl.oz followed by 3 applications 36 fl.oz |
| Methomyl 90% w.p. | 32 oz | 32 oz |
| Omethoate 57.5% e.c. | - | 16 fl.oz |

* Methamidophos is the proposed common name for Bayer 5546a

Aphid populations in the trials were assessed by recording adult apterae at frequent intervals on one upper, middle and lower leaf on one bine of each of 10 hills/plot giving 60 leaves/treatment on each occasion.

### Soil treatments

In screening tests in 1970 an experimental material now known as mephosfolan showed promise for use as a soil drench to control damson-hop aphid (Dicker 1971). In 1971-1973 the use of this material as a replacement for dimefox was investigated and various factors affecting the use of soil drenches studied.

In 1971 a soil drench of mephosfolan was compared with an untreated control, a standard dimefox drench and with two methidathion sprays applied with a knapsack sprayer, in a replicated trial on nursery hops cv. Brewer's Gold.

The remaining comparisons of rates and dates of application of mephosfolan drenches and granules were carried out on randomised blocks of single hill plots of mature cv. Cobbs at Wye College and were replicated 10 times except the trial on the uptake of mephosfolan which had five replicates. The method of assessment was the same as in the spray trials.

Rainfall data recorded at Wye College during the period of these trials is given in Fig.3 to assist in interpretation of the results.

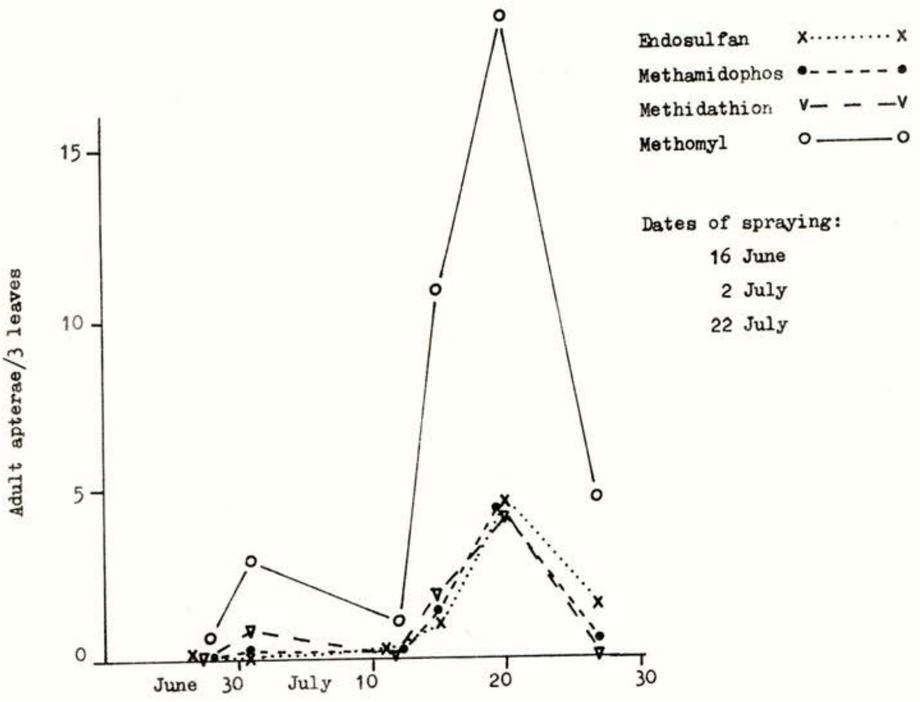
RESULTS

Sprays

Methamidophos, methidathion and methomyl gave good control in 1971 (Fig.1) but aphids built up rapidly on the endosulfan-treated plots in July and it was necessary to clean up those plants with another material at the end of the month. The intervals between applications in this trial may have been too long for endosulfan although the other materials were effective in this spray programme.

Fig.1

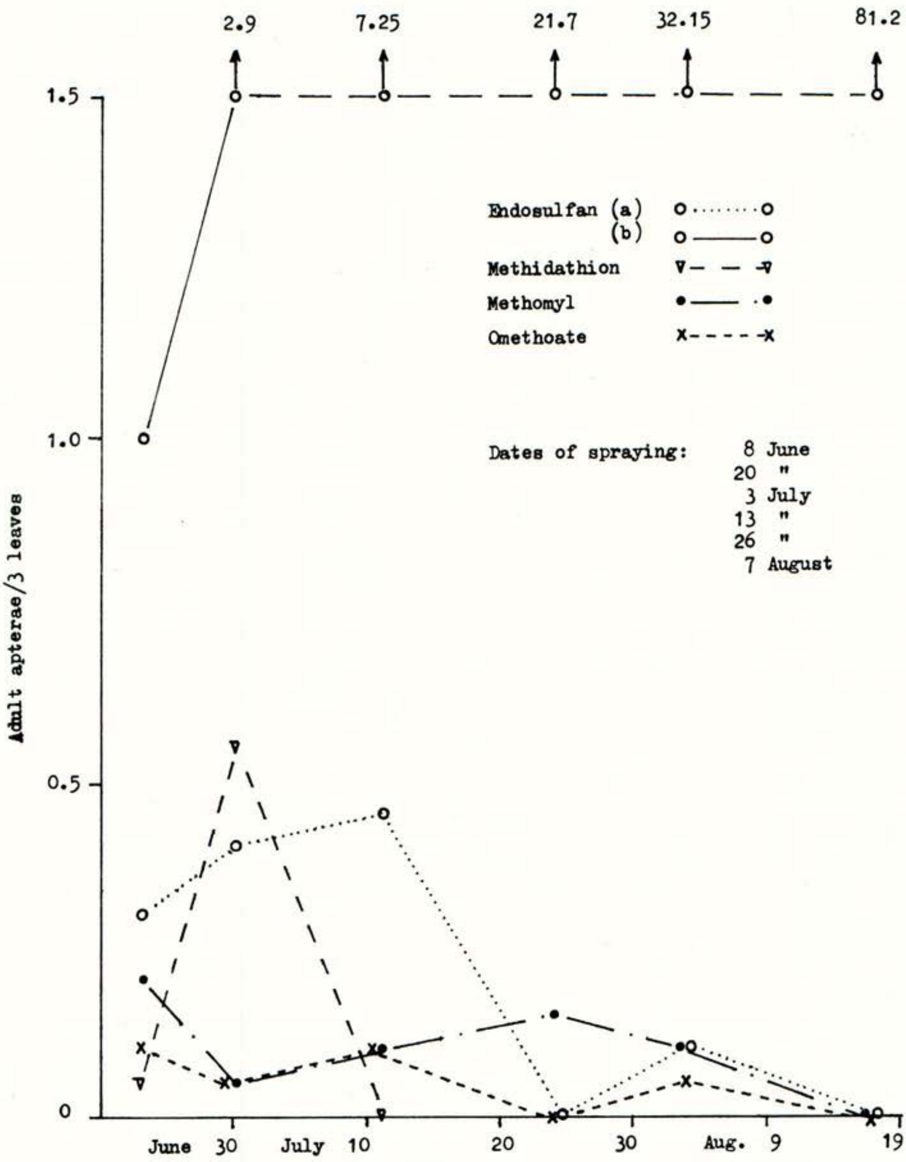
Comparison of spray materials 1971




In the 1972 trial methidathion, methomyl and omethoate all gave satisfactory control (Fig.2). The two endosulfan plots gave conflicting results and are therefore recorded separately; the control of the aphid on plot (a) was almost as good as that given by the other materials but the aphids multiplied rapidly from early in the season on plot (b) and reached a level which killed much of the foliage and severely reduced the yield of hops.

Fig.2

Comparison of spray materials 1972



Samples of cones from the plots were examined for aphids before the crop was picked.

Table 2

Percentage cones infested 5 September 1972

| Endosulfan (a) | Endosulfan (b) | Methidathion | Methomyl | Omethoate |
|---|---|---|---|---|
| 52 | 100 | 27 | 51 | 65 |

The samples of cones from all except endosulfan (b) were much cleaner than the figures suggest as there were very few aphids in each cone and no sign of aphids, honeydew or sooty mould on the exterior.

These trials showed little difference in effectiveness in controlling hop aphid between methamidophos, methidathion, methomyl and omethoate. (Methamidophos is not being actively developed for marketing at present.) However, it is evident in the field that on occasions the relative effectiveness of different materials may vary because of differences in sprayer, variety, husbandry or weather. In some conditions endosulfan has given good control although it did not prove to be reliable in these trials. Clearance was given under the Pesticide Safety Precautions Scheme for a higher rate of application to be used in 1973.

In the comparison of mephosfolan and dimefox soil drenches with methidathion sprays on nursery hops, both drench materials performed better than the sprays and prevented the development of adult apterae for nearly four weeks (Table 3).

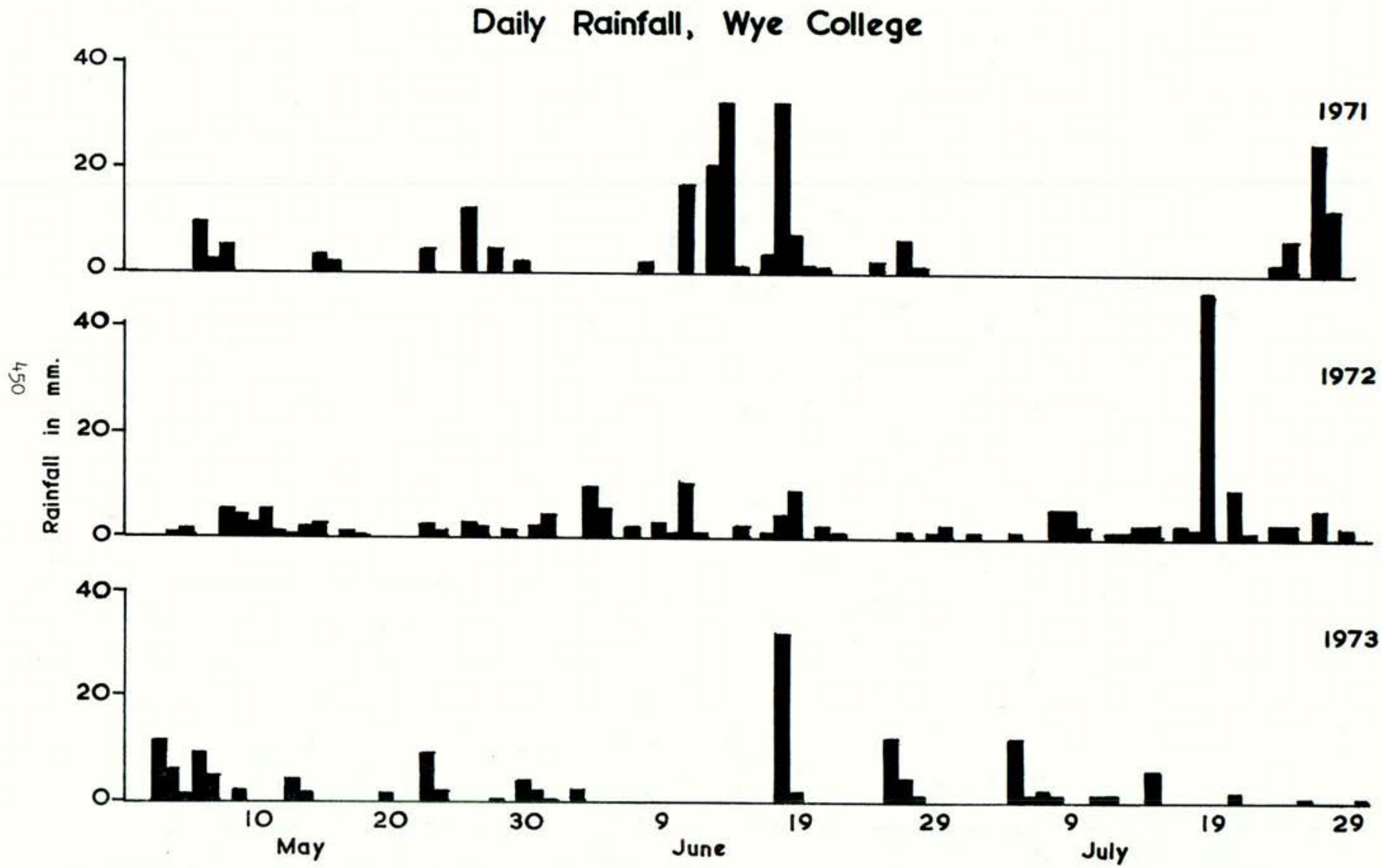
Table 3

Comparison of soil drenches and sprays 1971

| | Date of application | | | Adult apterae/3 leaves | | |
|---|---|---|---|---|---|---|
| | June | July | | July | | |
| | 22 | 5 | 21 | 5 | 16 | 29 |
| Untreated (until 16 July) | - | - | - | 304 | 249 | - |
| Methidathion sprays 18 fl.oz 40% e.c./100 gal | X | X | X | 1 | 30 | 12 |
| Mephosfolan drench 1 g a.i./hill | X | - | - | 0 | 1 | 20 |
| Dimefox drench 0.5 g a.i./hill | X | - | - | 0 | 1 | 3 |

In another comparison of mephosfolan and dimefox on mature hops in 1971 the first application of mephosfolan on 26 May kept the hills clean for between five and seven weeks, while dimefox had already broken down between three and five weeks from application (Table 4).

Fig.3



Daily Rainfall, Wye College
1971
1972
1973
40
20
0
Rainfall in mm.
10
20
30
9
19
29
May
June
July
450

Table 4

Comparison of drench materials

| Rate a.i./hill | | Adult apterae/3 leaves | |
|---|---|---|---|
| | 17 June | 29 June | 13 July |
| Days from application: | 22 | 34 | 48 |
| Untreated | 8 | 94 | 342 |
| Mephosfolan 1 g | 0 | 0 | 6 |
| Dimefox 0.5 g | 0 | 8 | 98 |

Mephosfolan and dimefox drenches were also applied to heavily infested hills in the same garden on 29 June. 8 mm rain had fallen in the two previous days (Fig.3) but no more rain fell until 24 July and neither material did more than check the aphids under these conditions. Caldicott (1973) also noted difficulty under similar conditions in 1972.

Rates and time of application

In 1972 mephosfolan drenches and 10% granules were applied at three rates and on three dates (Table 5). The granules were applied in narrow bands 20 cm on each side of the rows.

Table 5

Rates of a.i./hill (g) and dates of application in 1972 trial

| | Drench | Granules |
|---|---|---|
| 19 June | 1.0 | 1.0 |
| 17 July | 0.5 | 0.5 |
| | 0.75 | 0.75 |
| | 1.0 | 1.0 |
| 9 August | 0.5 | 0.5 |

Hills due to receive mephosfolan on 17 July and 9 August had been sprayed earlier in the season but both sets of hills were heavily infested at the time the mephosfolan was applied (see Fig.4).

Samples of 20 cones from each of 10 hills which received two of the treatments were examined for aphid infestation on 5 September.

Fig.4. Control given by soil drenches 1972

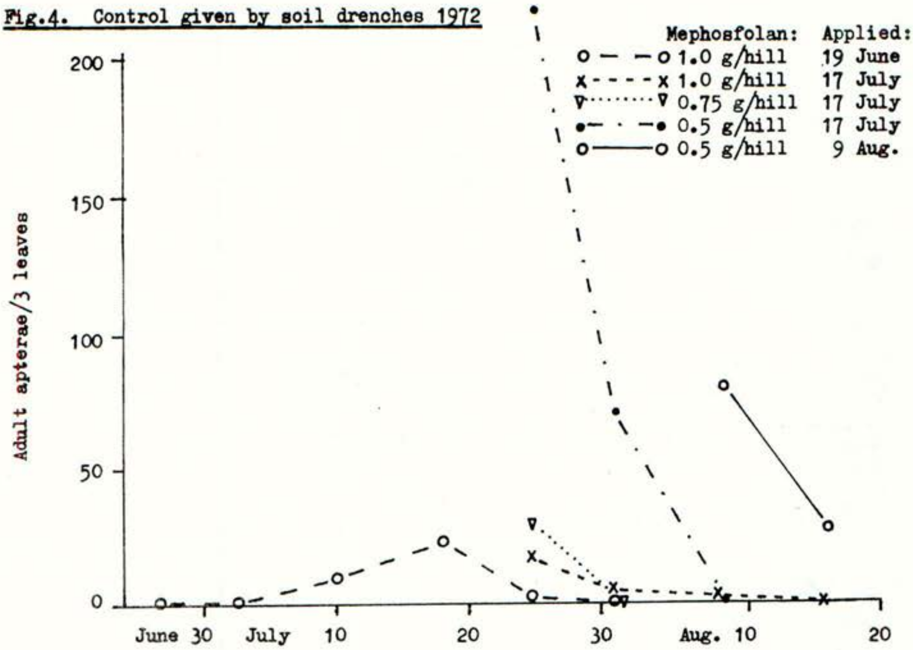



Fig.5. Control given by soil drenches 1973

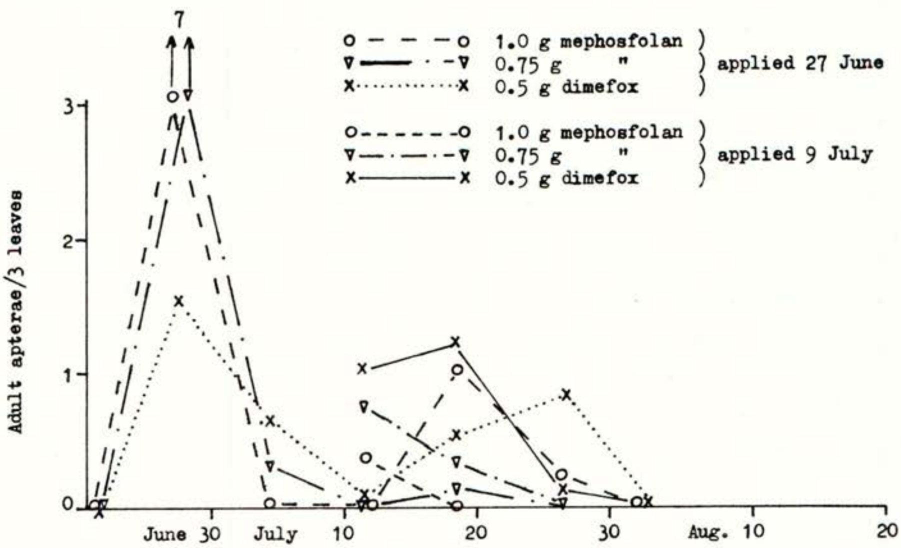


Table 6

Infestation of cones

| | % infested |
|---|---|
| 1.0 g mephosfolan drench, 19 June | 4.5 |
| 0.5 g " " , 9 August | 46.5 |

Apart from a temporary build-up about 10 July, 1.0 g mephosfolan/hill applied as a drench on 19 June kept the plants clean until the aphid migration finished at the end of July (six weeks), and only a few aphids were present on 4.5% of the cones on 5 September. 1.0 g and 0.75 g mephosfolan drenches applied on 17 July controlled a very heavy infestation within 12 days. Although 0.5 g mephosfolan drench applied on 17 July or 9 August killed many aphids, it was rather slow acting against these very heavy infestations and did not prevent infestation of the cones.

None of the granular treatments gave an acceptable level of control. The results of earlier trials with granular formulations of mephosfolan and other materials (Dicker 1971; Carden, P.W. unpublished) suggest that the active ingredients are not taken up by hop plants until after rain has fallen. This could apply to the failure of the June and August applications in this trial but control was also inadequate after almost 50 mm rain on the day following the July application. The results of another trial (Table 7) suggest that mephosfolan is largely taken up through the base of the bine rather than through the roots and this may account for the failure of the granules when applied under moist conditions.

In 1973 drenches of 1.0 g and 0.75 g a.i./hill were compared with dimefox on cv. Cobbs on two dates of application (Fig.5).

Aphid counts after the 0.75 g rate of drench were generally higher than after 1.0 g/hill but the difference was very small.

The June application of mephosfolan appears to have been slower acting than dimefox as there was some build-up of aphids six days after application, but otherwise mephosfolan applied on both dates performed slightly better than dimefox. The aphid population on untreated hills in this hop garden collapsed between 19 and 27 July, but by that time the June application had kept the hops clean for four to five weeks. No aphids were present on samples of cones from all treatments examined on 29 August.

Uptake of mephosfolan by the hop plant

Koch et al. (1969) showed that dimefox enters the hop plant through both the base of the bine and through the roots. More recent trials investigating methods of improving the uptake of dimefox when the soil was dry (Carden unpublished) confirmed this and showed that neither route on its own gave adequate control of the aphid. A similar trial in 1973 investigated the route by which mephosfolan enters the plant.

(i) 0.75 g a.i./hill was applied by the standard method - 4 fl.oz diluted material poured onto the crown of the plant wetting the lower 20 cm of the bines and the soil immediately round the bines.

(ii) 0.75 g a.i./hill was applied to the soil within 15 cm of, but not touching, the bine.

(iii) 12.5% mephosfolan was painted onto the lower 20 cm of bine only, at the rate of 2-4 ml ( 0.25-0.5 g a.i.) per hill on 22 June.

Table 7

Uptake of mephosfolan by the hop plant

| | Adult apterae/3 leaves | | | | | |
|---|---|---|---|---|---|---|
| | June | July | | | | August |
| | 28 | 5 | 11 | 19 | 27 | 2 |
| 0.75 g a.i. standard application | 9 | 4 | 3 | 1 | 0.3 | 0 |
| 0.75 g a.i. to soil only | 0.3 | 17 | 23 | 60 | 52 | 49 |
| c. 0.5 g a.i. to bine only | 0.3 | 0 | 2 | 0.3 | 0.7 | 0 |

The standard application gave fairly good control until the aphid population started to collapse four weeks after application, confirming the result recorded in Fig.5. Application to the soil only, gave quick but apparently very short-lived control. However, the reduced rate of active ingredient painted onto the bine appears to have worked at least as well as the standard application, indicating that much of the mephosfolan is absorbed by the base of the bine.

Volume of soil drenches

The uptake of dimefox and mephosfolan soil drenches by the hop plant is often prevented by lack of soil moisture. It seemed possible that application of the same rate of active ingredient in a greater volume of water might overcome this problem so in 1973 the effect of 0.75 g mephosfolan in 4, 8 and 40 fl.oz water/hill applied on 9 July was compared. The population of aphids collapsed soon after the treatments were applied but the standard amount of water gave much better initial control than higher volumes.

Table 8

Volume of soil drenches

| 0.75 g mephosfolan a.i. applied in | Adult apterae/3 leaves | | |
|---|---|---|---|
| | July | | August |
| | 19 | 27 | 2 |
| 4 fl.oz water/hill | 1 | 0 | 0 |
| 8 " " | 7 | 1 | 0 |
| 40 " " | 10 | 1 | 0 |

## CONCLUSIONS

Soil drenches of mephosfolan can give five or more weeks' protection of hops against damson-hop aphid. However, like dimefox, mephosfolan is dependent on the presence of soil moisture for uptake by the plant. In the 1971 trial, application on 29 June was not effective although 8 mm rain had fallen in two previous days (Table 3) suggesting that rain must fall after application of the drench for absorption to occur. In both 1971 and 1972 a mephosfolan drench gave more lasting protection against aphids when applied fairly early in the period of aphid migration (late May or mid June) than when applied in July (Tables 3 and 4, Fig.4). Campbell and Neve (1973) and Dennis (in lit.) have also reported similar results. More trials are necessary but it appears that a drench of mephosfolan applied in the last week of June should give protection until the first few days of August except during a drought. In these trials mephosfolan at 1.0 g a.i./hill gave very little better results than 0.75 g, but if protection is needed for less than four weeks 0.75 g a.i. should give satisfactory results.

If another year's trial confirms that the uptake of mephosfolan is largely through the bine and not the soil, this is an important difference from dimefox which must be allowed for when devising means of mechanical application of drenches. If appropriate safety measures can be devised, it might also be possible to reduce the amount of water needed and to improve uptake of the active ingredient in dry weather.

Application of a greater volume of drench per hill does not give as good control of the aphid as the standard 4 fl.oz. This is in line with the results of earlier trials carried out with dimefox (Carden unpublished).

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# THE CONTROL OF THE DAMSON-HOP APHID WITH mephosfolan*

J.J.B. Caldicott

Cyanamid of Great Britain Ltd., Gosport, Hampshire.

Summary In 8 replicated trials and 30 commercial type grower applications, mephosfolan drench at 1.0 g a.i. in 114 ml water/plant was shown to control Damson-Hop Aphid (*Phorodon humuli*) on hops for an approximate 6 week period from an application made in early July. The rate of 1.0 g a.i./plant gave superior aphid control to 0.5 g a.i./plant of either mephosfolan or dimefox. Mephosfolan at 0.75 g a.i./plant gave similar results to 1.0 g a.i. rate in a limited number of observations. In trials designed to determine the optimum time for application, the aphicidal activity was found to be influenced more by rainfall following the application than by the date of application. Satisfactory control of aphids on the foliage and in the cones was achieved in the majority of the grower trials by 3 to 4 insecticide sprays followed by a mid-season drench of mephosfolan.

## INTRODUCTION

Mephosfolan is the proposed common name for 2-(diethoxyphosphinylimino)-4-methyl-1, 3-dithiolane also known as EI 47470. This systemic broad spectrum insecticide was described by Lindley (1971) who recorded its activity in cotton, rice and maize.

The first records of the activity of mephosfolan against the Damson-Hop Aphid, (*Phorodon humuli*), were made by Dicker (1971, 1972, 1973) who carried out field bio-assay studies at East Malling Research Station, Kent. Mephosfolan, applied as a soil drench at 1.0 g a.i. in 228 ml water/plant, during the years 1970-1972, allowed less than 5% survival of nymphs for periods ranging between 4 weeks and 11 weeks depending on the amounts and intervals of rainfall after the applications of the drench.

Following the initial successful result at East Malling in 1970 field trials were organised in 1971 and 1972 by Cyanamid of Great Britain Limited, by A.D.A.S. officers at Wye, Kent and at Rosemaund E.H.F., Herefordshire and by the Hop Research Department at Wye College.

This paper describes 8 replicated trials and 30 grower trials conducted by Cyanamid of Great Britain Limited.

## METHODS AND MATERIALS

In all experiments an emulsifiable concentrate formulation of mephosfolan containing 250 g a.i./litre was used. All dosage rates are expressed in terms of active ingredient per plant throughout this report.

* Provisionally Approved BSI Common Name

Replicated trials 1971: 4 trials were conducted in commercial hop gardens in Kent to compare soil drenches of mephosfolan at 1.0 g and 0.5 g/plant with the recommended dimefox soil drench at 0.5 g/plant. Randomised block designs were used with each treatment being replicated 4 times. There were no untreated controls. Treatments were applied near the beginning of the aphid invasion between June 3 and June 7. The efficacy of treatments was assessed by counting late instar nymphs and mature adult wingless aphids on hop foliage so that treatments could be compared on a "surviving aphids per leaf" basis.

Replicated trials 1972: 4 trials were conducted in commercial hop gardens in Kent. In 2 of these soil drenches of mephosfolan applied in early July at 1.0 g and 0.75 g/plant were compared. In the other 2 trials mephosfolan drench at 1.0 g/plant was applied successively at weekly intervals over 5 weeks to different plots from June 19 to July 17. In both series of trials randomised block designs were used. There were 4 replicates of each treatment in the rate trials and 3 in the timing trials. Aphids were assessed on the foliage at weekly intervals and, on the timing trials, in the cones at harvest.

In all the above trials the treated plots comprised 3 rows x 6 or 7 plants. Assessments were carried out only on the central 4 or 5 plants in each plot. The leaves examined were taken from the 4th node back from the growing point from 4 leading shoots per plant. In all cases the hops were grown on the 'Kent' planting system of approximately 6 ft squares; 8 bines on 4 strings being taken from each root stock.

Grower trials 1972: Growers at 15 sites in the West Midlands of England and at 15 sites in Kent applied mephosfolan drench to half an acre of hops. These applications were monitored by staff of Cyanamid of Great Britain Limited and growers were asked to complete a questionnaire on the details and results of their applications. In addition hop cones were taken at harvest and examined for aphid infestation. Mephosfolan drench usually at 1.0 g/plant but sometimes also at 0.75 g and 0.5 g/plant was compared with dimefox soil drench at 0.5 g/plant in the West Midlands trials and in some Kent trials. In the other Kent trials comparison was with routine spray programmes. Drench treatments were applied between June 12 and August 7 but with 40% of them being made during the week commencing July 17. The greater number of these applications were made using a Phillips tractor mounted applicator. In most cases 4 foliar sprays were applied prior to the drench treatment. A total of 13 varieties was covered in these trials.

## RESULTS

All trials relied upon natural rainfall and soil moisture and natural invasion of winged aphids. In 1971 the winged aphid invasion commenced in the 3rd week of May and lasted until the 1st week of August. In 1972 the invasion commenced in the 1st week of June and continued until the 2nd week of August. In 1971 during the period June 4-25 rainfall was heavy (more than 100 mm at 3 sites) whereafter there followed almost 4 weeks of very hot, dry weather. In 1972 there were only isolated falls of rain in June and early July but greater amounts were recorded in late July and early August.

### Replicated Trials

Rate comparisons 1971: Tables 1-3 give the weekly record of live aphid numbers per leaf in the 4 trials conducted in 1971. The levels of aphid control varied considerably between treatments.

## Table 1

Mean number of surviving adult aphids per leaf at site 1 - 1971

Mid-Kent, var. OR 55 - Soil wet at treatment

| Treatments | | A | B | C |
|---|---|---|---|---|
| Mephosfolan | g a.i./plant - early June | 0.5 | 1.0 | - |
| Dimefox | g a.i./plant - early June | - | - | 0.5 |

| Weeks from treatment | Rainfall for preceding week mm. | Mean number live aphids/leaf | | |
|---|---|---|---|---|
| 1 (June 10th) | 28 | 0.19 | 0 | 0.25 |
| 2 | 46 | 0.91 | 0 | 0.03 |
| 3 | 24 | 0.03 | 0 | 0 |
| 4 | 8 | 0.06 | 0 | 0 |
| 5 | 0 | 0.44 | 0 | 0.41 |
| 6 | 0 | 1.63 | 0.28 | 1.28 |
| 7 (July 22nd) | 0 | 8.06 | 1.22 | 4.28 |

Mephosfolan at 1.0 g/plant gave complete or virtually complete control for at least 5 weeks after treatment at sites 1, 2 and 3. Thereafter aphids increased to a maximum at 6 to 8 weeks after treatment, slightly in excess of one adult per leaf. At site 4 after an initial peak 2 weeks after treatment, aphid numbers remained below 0.5 adults per leaf. At sites 1 and 4 mephosfolan and dimefox at 0.5 g/plant gave similar control. At sites 2 and 3 the control achieved by mephosfolan at 0.5 g was superior to dimefox but it was necessary to re-apply both treatments between 4 and 7 weeks after the original application. Despite the re-treatment a high level of control was not achieved.

Rate comparisons 1972: Table 4 gives the weekly records of live aphid numbers per leaf in the 2 rate comparison trials conducted in 1972. At site 5 mephosfolan at both the 1.0 g and 0.75 g rates allowed a low level of survival of aphids until July 31 (5 weeks after treatment) but after the end of aphid fly-in the numbers fell to zero by August 21. At site 6 reasonable control of aphids was achieved by both rates until the end of aphid fly-in but by 8 weeks aphids were found on plants treated at both rates though detailed counts were not made.

Timing comparisons 1972: Table 5 gives the weekly records of live aphids per leaf in the 2 timing comparison trials conducted in 1972. At site 7 aphid numbers on mephosfolan treated plots did not show a decline until the count on July 24 after which they fell dramatically. It is likely that aphids continued to increase after the assessment of July 10 reaching a peak a few days later after which the effects of rain on July 9 caused a decline so that counts on July 17 gave much the same reading as a week earlier. A mid week count might have displayed this peak. No aphids were found in any of the treatments after early August either on the foliage or in the cones at harvest. At site 8 reasonable control of aphids was exerted by all drench treatments except in the case of the June 19 application which gave signs of breaking down on August 14, 8 weeks after application; this result was, however, influenced by high readings on a few individual bines only. Despite the low level of aphid infestation on treated plots, the influence of rain on July 9 and July 20-25 was reflected in lower aphid counts on all plots a week later in each case.

## Table 2

**Mean number of surviving adult aphids per leaf at sites 2 and 3 - 1971**

| Treatments | | | A | B | C |
|---|---|---|---|---|---|
| Mephosfolan | g a.i./plant | - early June | 0.5 | 1.0 | - |
| | | - July | 0.5 | - | - |
| Dimefox | g a.i./plant | - early June | - | - | 0.5 |
| | | - July | - | - | 0.5 |

| Weeks from treatment | Rainfall for preceding week mm. | Mean number live aphids/leaf | | |
|---|---|---|---|---|
| **Site 2.** North Kent, var. Goldings - Soil wet at treatment on June 7th | | | | |
| 1 (June 14th) | 55 | 1.56 | 0.31 | 2.08 |
| 2 | 10 | 0.14 | 0 | 0.31 |
| 3 | 4 | 0.50 | 0 | 2.39 |
| 4 | 0 | 0.75 | 0.14 | 13.9** |
| 5 | 0 | 0.67 | 0 | 0.33 |
| 6 | 0 | 0.61 | 0.11 | 2.31 |
| 7 | 10 | 1.28** | 0.17 | 1.31 |
| 8* | 12 | 2.44 | 0.25 | 5.22 |
| 9 | 9 | 0.36 | 1.06 | 4.03 |
| 10 (August 16th) | 2 | 0.14 | 0.28 | 2.11 |
| **Site 3.** Mid-Kent, var. Northern Brewer - Soil wet at treatment on June 4th | | | | |
| 1 (June 11th) | 28 | 0.03 | 0 | 0 |
| 2 | 59 | 0.28 | 0 | 0.38 |
| 3 | 23 | 0.81 | 0 | 5.91 |
| 4 | 9 | 0.41 | 0 | 2.63 |
| 5 | 0 | 2.16** | 0.03 | 4.75** |
| 6 | 0 | 3.31 | 0.34 | 10.3 |
| 7 | 0 | 2.78 | 1.13 | 15.1 |
| 8* | 0 | 1.50 | 0.69 | 9.94 |
| 9 | 17 | 0.16 | 0.28 | 14.8 |
| 10 (August 13th) | 19 | 0 | 0.03 | 1.63 |

* end of winged aphid fly-in   ** treatment re-applied after counting

**Grower Trials 1972**

In 30 commercial type applications of mephosfolan drench at 1.0g/plant hops were kept clean of aphids from application to harvest without further chemical treatment at 14 sites and with one further foliar spray at 9 sites. At 7 sites growers resumed routine foliar sprays believing the drench not to have worked adequately. At the 14 sites where no subsequent foliar sprays were applied between 2% and 10% dirty cones were found at 5 but at the remaining 9 sites cones were completely clean. At the 9 sites where one extra foliar spray was applied the cones were clean at harvest. Repeated foliar sprays after drenching at the remaining 7 sites masked the effect of mephosfolan. At 20 sites mephosfolan was directly compared with dimefox at 0.5 g/plant. At 6 of these mephosfolan gave longer control of aphids on the foliage but in only 3 were there more aphids in the cones from the dimefox treated plants. The use of the Phillips tractor mounted applicator was satisfactory but at three sites where mephosfolan was sprayed under pressure on to the base of the plants the aphid control was poor.

## Table 3

**Mean number of surviving adult aphids per leaf at site 4 - 1971**

North Kent, var. Bramling Cross - Soil wet at treatment

| Treatments | | A | B | C |
|---|---|---|---|---|
| Mephosfolan | g a.i./plant - early June | 0.5 | 1.0 | - |
| Dimefox | g a.i./plant - early June | - | - | 0.5 |
| | - July | - | - | 0.5 |

| Weeks from treatment | Rainfall for preceding week mm. | Mean number live aphids/leaf | | |
|---|---|---|---|---|
| 1 (June 11th) | 26 | 1.06 | 0.47 | 1.00 |
| 2 | 78 | 2.41 | 1.66 | 2.59 |
| 3 | 20 | | | |
| 4 | 10 | 2.56 | 0.33 | 2.19** |
| 5 | 0 | | | |
| 6 | 0 | 0.88 | 0.19 | 1.44 |
| 7* | 0 | 0.88 | 0.56 | 0.78 |
| 8 | 0 | 1.66 | 0.22 | 0.47 |
| 9 (August 6th) | 35 | 2.09 | 0.44 | 1.41 |

## Table 4

**Mean number of surviving adult aphids per leaf at sites 5 and 6 - 1972**

| Treatments | | A | B |
|---|---|---|---|
| Mephosfolan | g a.i./plant | 1.0 | 0.75 |

| Weeks from treatment | Rainfall for preceding week mm. | Mean number live aphids/leaf | |
|---|---|---|---|
| **Site 5.** Mid-Kent, var. Northern Brewer - Soil dry at treatment on July 3 | | | |
| 1 (July 10th) | 9 | 1.0 | 1.0 |
| 2 | 0 | 0.3 | 0.5 |
| 3 | 44 | 0.3 | 3.3 |
| 4 | 0 | 2.2 | 1.8 |
| 5* | 19 | 0.3 | 1.3 |
| 6 | 12 | 0.5 | 2.5 |
| 7 (August 21st) | 0 | 0 | 0 |
| **Site 6.** North Kent, var. Wye Challenger - Soil moist at treatment on July 10 | | | |
| 1 (July 17th) | 0 | 1.3 | 0.7 |
| 2 | 30 | 0 | 0 |
| 3 | 4 | 0.2 | 0.3 |
| 4* | 19 | 0.2 | 0.7 |
| 5 | 8 | 0 | 0 |
| 6 | 10 | 0 | 0 |
| 7 | 0 | | |
| 8 (September 6th) | 0 | some† | some† |

* end of winged aphid fly-in

** treatment re-applied after counting

† aphids observed on foliage but no detailed counts made

Table 5

Mean number of surviving adult aphids per leaf and numbers of infested cones at harvest following mephosfolan drench treatments at different dates. Sites 7 and 8 - 1972

| Treatments | A | B | C | D | E | Soil moisture status at both sites |
|---|---|---|---|---|---|---|
| Mephosfolan g a.i./plant | | | | | | |
| applied June 19 | 1.0 | | | | | dry |
| June 26 | | 1.0 | | | | dry |
| July 3 | | | 1.0 | | | dry |
| July 10 | | | | 1.0 | | moist |
| July 17 | | | | | 1.0 | dry |

Site 7. North Kent, var. Goldings

| | Mean no. live aphids/leaf | | | | | Rainfall for preceding week mm. |
|---|---|---|---|---|---|---|
| June 26 | 1.7 | | | | | 2 |
| July 3 | 1.1 | 3.4 | | | | 1 |
| July 10 | 16.3 | 30.5 | 52.5 | | | 10 |
| July 17 | 15.2 | 42.0 | 32.0 | 10.2 | | 0 |
| July 24 | 0.3 | 1.3 | 1.0 | 0.3 | 0.2 | 5 |
| July 31* | 0.2 | 0.7 | 0.5 | 0.5 | 0 | 11 |
| August 7 | 0 | 0.03 | 0 | 0 | 0 | 8 |
| August 14 | 0 | 0 | 0 | 0 | 0 | 5 |
| August 28 | 0 | 0 | 0 | 0 | 0 | |

Cones categorised for % aphid infestation

| Sept 18 | | | | | |
|---|---|---|---|---|---|
| Infested cones | 0 | 0 | 0 | 0 | 0 |
| Clean cones | 100 | 100 | 100 | 100 | 100 |

Site 8. Mid-Kent, var. Northern Brewer

| | Mean no. live aphids/leaf | | | | | Rainfall for preceding week mm. |
|---|---|---|---|---|---|---|
| June 26 | 0.5 | | | | | 5 |
| July 3 | 0.3 | 0 | | | | 4 |
| July 10 | 1.7 | 0 | 2.0 | | | 9 |
| July 17 | 0.3 | 0 | 0 | 0.1 | | 0 |
| July 24 | 2.6 | 1.5 | 0.5 | 0 | 0 | 44 |
| July 31 | 1.6 | 1.0 | 0.2 | 0 | 0 | 0 |
| August 7* | 2.8 | 1.3 | 1.5 | 0 | 0 | 19 |
| August 14 | 5.3 | 1.0 | 1.7 | 0 | 0 | 12 |
| August 28 | | 0 | 0 | 0 | 0 | |

Cones categorised for % aphid infestation

| Sept 20 | | | | | |
|---|---|---|---|---|---|
| Infested cones | | 8.0 | 6.0 | | 3.0 |
| Clean cones | | 92.0 | 94.0 | | 97.0 |

* end of winged aphids fly-in

Rainfall at these grower trial sites was not accurately recorded but, particularly in Kent, June and July were largely dry months. Dry weather at application delayed the effects of mephosfolan in at least some cases and the resumption of foliar spraying by some growers was, undoubtedly, premature. Further points noted in some grower trials indicated that, a) A better post-drench control of aphids was achieved when hop plants were clean at the time of drenching than when they were badly infested with aphids, and, b) Control of aphids on certain individual bines was sometimes less good than on the rest of the plant; a phenomenon well known in relation to dimefox drench. This may be attributable either to the emergence of individual bines away from the main crown of the plant where this occurred or to the presence of weeds or dead leaves around the base of the plants which acted as a barrier preventing satisfactory uptake of mephosfolan into the hop plant.

Safety to hops and effects on quality

No instance of phytotoxicity of mephosfolan to hop plants were recorded in either technical or grower trials. Tests for alpha acid content of treated hops by Wye College and by Birmingham University and for taints or off flavour in beer brewed from treated hops by Birmingham University showed no adverse effects attributable to mephosfolan.

## DISCUSSION

In the 1971 rate comparison trials mephosfolan at 1.0 g/plant in early June gave much better control of aphids and was more persistent than either mephosfolan at 0.5 g or dimefox at 0.5 g/plant. In the 1972 rate comparison trials the 0.75 g/plant rate gave virtually as good a control in two trials as did the 1.0 g rate. The 0.75 g rate was also tested in 1972 by Carden (1973) and at Rosemaund E.H.F. (Anon 1972) and in two of the grower trials. This 0.75 g rate gave satisfactory results in the limited number of tests but more information is required before it could be recommended.

In the 1972 timing trials the object was to establish the optimum date for application of mephosfolan as a soil drench to control aphids on hops right through the invasion period so as to obtain clean cones at harvest. The achieving of this goal is obviously affected by rainfall after the application of the drench and probably, also, by the soil moisture status at the time of application. The summer of 1972 was particularly dry in Kent. There were 4 distinct peaks of rainfall at sites 7 and 8 on July 9, July 21-25, August 1-2 and August 12. In most cases these falls were less than 9 mm though 33 mm were recorded at site 8 on July 21. Frequently the effects of these periods of rain could be seen in reduced aphid numbers a week or so later. At site 7 on North Kent brick earth the relatively light fall of 10 mm in the week preceding July 10 was sufficient to reduce aphids to a low level by late July/early August and to give clean cones at harvest. At site 8 on weald clay, although aphid infestation was at a low level the late June/early July applications had difficulty in bringing numbers under control despite the July 9 rain, whereas application on July 10 and 17, which was followed by 44 mm of rain, had an immediate effect and maintained foliage free from aphids for the rest of the season. This difference in response to rainfall amounts may have been due to difference in soil type or soil structure.

The 2 timing trials did not give a clear cut answer as to the optimum date of application but in the circumstances in which they were conducted the application dates of July 10 and July 17 gave the best results. In the grower trials 60% of all applications were made during these 2 weeks.

From the recorded data available, including that of Dicker (1971, 1972, 1973), Carden (1973) and Rosemaund E.H.F. (Anon 1972) a persistence of approximately 6 weeks control of *Phorodon humuli* on hops can be expected following a mid-season application of mephosfolan to the soil at the base of hop plants at the rate of 1.0 g/plant. To obtain control through to the end of aphid fly-in in mid-August an application of mephosfolan, on the basis of this evidence, could be made in early July. However, activity may be delayed if the application is made in dry weather. Residue data currently available restrict the use of mephosfolan to 9 weeks before harvest, thus an early July application will allow a mid-September harvest. It is hoped in the course of further work to reduce this minimum interval from application to harvest.

The 30 grower trials indicated that satisfactory commercial results can be obtained from a programme employing 3 to 4 foliar sprays commencing late May or early June followed by an application of mephosfolan drench in early to mid-July. In dry conditions a further foliar spray may be required in the event of delayed uptake of mephosfolan. The Phillips tractor mounted applicator proved a suitable tool for the application of mephosfolan drenches.


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# OMETHOATE - A NEW INSECTICIDE FOR THE CONTROL OF DAMSON-HOP APHID IN ENGLAND

D C Clark & R J Lloyd

Bayer Agrochem Ltd, Eastern Way, Bury St Edmunds, Suffolk

Summary Omethoate, an organophosphorus insecticide, was evaluated in a series of field trials.

Individual sprays of omethoate gave an initial kill of aphids that was slower than, but as complete as that obtained with the contact insecticides used as standards. Following this clean-up, control was obtained over a longer period than that provided by the standards. It is suggested that the systemic nature of the insecticide is responsible for its effectiveness.

Clean hops were obtained with programmes of both omethoate and standards, but this result was achieved with fewer sprays of omethoate at longer intervals. This reduced programme kept aphid numbers at a lower level.

These effects have been consistently demonstrated in two years trials and two years commercial usage of omethoate at 0.057% a.i. HV or 9.2 - 18.4 oz a.i./acre MV.

## INTRODUCTION

The resistance of field strains of Damson-hop aphid (Phorodon humuli) to certain contact and systemic organophosphorus insecticides is well established Anon (1970), Dicker (1971, 1972). The widespread presence of resistant populations is now accepted Anon (1973). The introduction in 1970 of two contact insecticides alleviated the situation, but these needed to be applied at short intervals to existing populations of the aphid.

Omethoate, a systemic organophosphorus insecticide/acaricide, developed by Bayer AG, has been shown to be effective for the control of resistant strains of Red spider mite and aphids, Kolbe (1966) and Dicker (1972). This material has been widely used on hops and fruit crops in Europe, and when it became available in the UK a programme of evaluation was undertaken to assess its value for Damson-hop aphid control in England.

## METHOD AND MATERIALS

Trials on hops were carried out in 1971-1972 using omethoate formulated as a 57.5% w/v liquid concentrate coded Bayer 5089a. Omethoate is the accepted common name of O,O-dimethyl-S-(N-methylcarbamoylmethyl)-phosphorothioate.

Omethoate has full commercial clearance under the Pesticides Safety Precautions Scheme for use on hops, apples and winter cereals with a harvest interval of 3 weeks.

Six small plot trials were laid down using plots of six hills (stocks) replicated three times. Treatments were applied to run off (HV) using knapsack air-assisted sprayers or an Allman Rapid Mk V with hand lances.

Fifteen grower trials were carried out using unreplicated plots of 1-2 acres, the treatments being applied by growers own machinery, usually air-assisted sprayers. Where HV was used water volumes of 50-400 gal/ac were employed, increasing as the season progressed, at all times using omethoate of 0.057% a.i. For the MV trials volumes of 30-100 gal/ac were employed with an increasing rate of omethoate per acre as below:

| | |
|---|---|
| Start of migration - end June | 9.2 oz a.i./acre |
| Early - mid July | 13.8 oz a.i./acre |
| Late July - August | 18.4 oz a.i./acre |

In all trials omethoate was compared with one or two commonly used hop insecticides, methidathion (40% ec) and propoxur (50% wp) at manufacturers' recommended rates. The first application of all treatments was made at the start of aphid migration in early June. Repeat applications were made to individual plots when aphid populations reached an unacceptable level, usually when the presence of adult apterae was discovered. The timing of applications in the grower trials was determined by the grower concerned.

Counts and observations of the aphid populations were made throughout the season, with the cone infestation and condition assessed at harvest. At each count at least five pairs of leaves per plot were examined, these being selected from the most recently expanded leaves near the growing point, or on laterals. Following the June applications, assessments were made within 3-4 days of last treatment and again 5-23 days later.

Crop tolerance and biological compatibility trials were laid down using unreplicated plots ranging from 10 hills to 1 acre, observations being made of any foliar and cone symptoms.

## RESULTS

Results from replicated trials are presented in Tables 1, 2 and 3, those from grower trials in Table 4 and a summary of all trials in Table 5.

### Table 1

### Initial Control 1971-72

Mean number of total aphids/leaf 3-4 days after a single June application

| Site | | Kent 3/71 | Kent 4/71 | Hereford 1/72 | Kent 2/72 |
|---|---|---|---|---|---|
| Cultivar | | OR55 | 1147 | Fuggle | OR55 |
| Days after treatment | | 3 | 4 | 4 | 3 |
| Omethoate | 0.057% a.i. | 0.1 | 0.1 | 7.5 | 0 |
| Propoxur | 0.075% a.i. | 0.4 | 0.0 | 8.4 | 0 |
| Methidathion | 0.05% a.i. | | 0.9 | | |
| Untreated | | 136.0 | 17.2 | 77.4 | 19.9 |

### Table 2

### Long Term Control 1971-72

Mean number of total aphids/leaf 9-22 days after a single June application

| Site | | Hereford 1/71 | Hereford 2/71 | Kent 3/71 | Kent 4/71 | Hereford 1/72 | Kent 2/72 |
|---|---|---|---|---|---|---|---|
| Cultivar | | Fuggle | N Brewer | OR55 | 1147 | Fuggle | OR55 |
| Days after treatment | | 13 | 22 | 17 | 19 | 12 | 9 |
| Omethoate | 0.057% a.i. | 19.1 | 3.3 | 16.5 | 17.5 | 2.3 | 4.6 |
| Propoxur | 0.075% a.i. | 75.5 | 62.0 | 43.0 | 57.7 | 41.9 | 13.0 |
| Methidathion | 0.05% a.i. | 89.9 | | | 110.7 | | |
| Untreated | | 625.0 | | 143.0 | 121.8 | 195.0 | 64.4 |

Tables 1 and 2 give total number of aphids, while table 3 gives numbers of adult aphid from three typical trials.

## Table 3

### Long Term Control of Adults 1971-72

Mean number of adult apterae (AD) and alatae (AL) following a single June application

| Site | Kent 3/71 | | Kent 2/72 | | Hereford 1/72 | |
|---|---|---|---|---|---|---|
| Days after treatment | 19 | | 22 | | 26 | |
| Treatment | AL | AD | AL | AD | AL | AD |
| Omethoate | 0 | 0 | 1.3 | 0 | 0.2 | 0.2 |
| Propoxur | 2.5 | 3.7 | 1.2 | 3.2 | 0.8 | 13.2 |
| Methidathion | 3.1 | 20.1 | | | | |
| Untreated | 5.0 | 38.5 | 2.4 | 21.3 | 0.5 | 80.0 |

Table 4 shows results from selected trials where the spray timing was determined by the grower.

## Table 4

### Control in Grower Trials 1972

Mean number of Alate (AL) and total apterae (AP) per leaf assessed in

| Site | cv. | Treatment | JUNE AL | JUNE AP | | JULY AL | JULY AP | |
|---|---|---|---|---|---|---|---|---|
| Hants 3/72 | Fuggle | Omethoate | 0.05 | 0 | (7) | | | |
| | | Propoxur | 2.6 | 10.9 | | | | |
| Kent 4/72 | Cobbs | Omethoate | 0.2 | 1.2 | (11) | 0.2 | 2.0 | (9) |
| | | Methidathion | 2.5 | 32.3 | | 2.7 | 53.0 | |
| Kent 5/72 | Eastwell Golding | Omethoate | 0.2 | 1.7 | (11) | 0.0 | 0.7 | (9) |
| | | Methidathion | 1.0 | 14.6 | | 3.8 | 39.5 | |
| Kent 6/72 | Progress | Omethoate | 0.2 | 1.6 | (14) | 0.0 | 0.3 | (7) |
| | | Methidathion | 0.8 | 36.2 | | 0.2 | 3.8 | |
| Kent 7/72 | OT 48 | Omethoate | 0.1 | 12.7 | (14) | 0.0 | 0.0 | (7) |
| | | Methidathion | 1.2 | 22.6 | | 0.0 | 3.3 | |
| Kent 8/72 | OT 48 | Omethoate | 0.0 | 0.5 | (7) | | | |
| | | Methidathion | 0.2 | 5.4 | | | | |

Figures in brackets refer to the number of days between assessment and the previous spray in the programme.

An insecticidal programme, as well as keeping down aphid populations to a non damaging level, is also designed to provide cones free of blemish and aphid infestation. The latter was achieved with all spray programmes in the trials.

Table 5

Summary of Spray Programmes and their Effectiveness

| Site | | Standard used | Total No.of Sprays | | Average Interval days | | Mean aphids/leaf throughout assessments | |
|---|---|---|---|---|---|---|---|---|
| | | | Omethoate | Standard | Omethoate | Standard | Omethoate | Standard |
| Hereford | 1/71 | (M) | 4 | 5 | 22 | 17 | 30.3 | 81.8 |
| Kent | 4/71 | (M) | 3 | 3 | 34 | 18 | 5.4 | 27.3 |
| Kent | 4/72 | (M) | 4 | 7 | 19 | 13 | 3.2 | 32.3 |
| Kent | 5/72 | (M) | 5 | 7 | 19 | 13 | 1.3 | 17.9 |
| Kent | 6/72 | (M) | 5 | 6 | 17½ | 14 | 4.3 | 17.6 |
| Kent | 7/72 | (M) | 4 | 4* | 18 | 16 | 0.5 | 4.3 |
| Kent | 9/72 | (P) | 6 | 9 | 15 | 8½ | 2.7 | 9.1 |
| Hants | 3/72 | (P) | 4 | 7 | 22 | 15 | ** | |
| Kent | 8/72 | (M) | 6 | 6 | 11 | 11 | ** | |
| Hereford | 10/72 | (M) | 5 | 6 | 12 | 10 | 12.4 | 47.7 |
| Mean | | | 4.6 | 6 | 18.9 | 13.5 | 7.51 | 29.75 |

P = Propoxur

M = Methidathion

* = Final spray of omethoate following three of standards

** = Insufficient assessments to give reliable mean

Small plot trials indicated that a single spray of omethoate gave an 80% control of red spider, and observations of commercial usage showed that a programme of 4-5 sprays will keep the spider mite population down to a low level.

## Crop Tolerance and Compatibility

During the development programme and commercial usage between 1971-73 all commercially grown hop cultivars have been treated with omethoate, including the newer cultivars Wye Target, Wye Challenger, Wye Northdown and the continental cultivars Hallertauer and Saazer.

During the MV trials programme marginal chlorosis was observed on the lower lateral leaves in two Golding cultivars. This was noted in late July after 3-4 applications of omethoate and may have occurred as a result of applying high concentrations (2-3 times normal HV rate) to run off in the area close to the sprayer. A full examination of this phenomenon was made by treating a range of cultivars with 2-3 closely spaced sprays at twice normal concentration. Under these conditions symptoms could be reproduced on certain cultivars, however at standard concentration and the normal spray interval the symptoms were faint or absent.

Compatibility trials using omethoate with the most commonly used hop fungicides, foliar feeds and acaricides indicated that these mixtures were both safe to the crop and effective.

A taint trial has shown beer brewed from hops treated with a programme of omethoate to have a similar flavour and aroma to the control beer.

## DISCUSSION

Observations made 1-2 days after spraying indicated that much of the aphid population was moribund, but complete kill of aphid was usually achieved with omethoate within 3-4 days of application. The initial kill with omethoate was similar to that achieved with the contact insecticides used as comparisons, but 9-22 days after application aphid populations on the omethoate treated hops were much lower indicating persistence. This effect was consistent in all trials. The recolonisation of omethoate treated hops by winged aphids does not occur for 7-14 days, and subsequently the development of adult apterae is delayed accordingly.

Efficient translaminar action of omethoate has been shown by Dicker (1973). The marginal chlorosis experienced in some cases, suggests that the compound or its metabolite is moved within the leaf and concentrated in the leaf margin. This property has previously been reported for another systemic organophosphorus compound Tietz (1954).

Crop tolerance and compatibility have proved satisfactory, and have permitted widespread use of omethoate on the English hop crop since its commercial introduction in 1973. In 1973 aerial application of omethoate, at 18.4 oz a.i. in 2 gal/ac water, has been used successfully to clean up infestations at the top of very dense crops.

Omethoate is shown to be a highly effective compound for the control of Damson-hop aphid, providing a season's control with fewer sprays at longer intervals than the recently introduced contact insecticides.

## Acknowledgements

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# COMPARISON OF FUNGICIDES AND METHODS OF APPLICATION FOR THE CONTROL OF RAMULARIA LEAFSPOT OF STRAWBERRY

A. O. Paulus, V. Voth and R. S. Bringhurst
Univ. Calif., Plant Pathology and Pomology Dept., Riverside and Davis
N. Welch
Univ. Calif. Agric. Ext. Service, Watsonville, Calif.

Summary Benomyl or thiophanate-methyl applied as dips to strawberry nursery plants before planting provided significantly better control of *Ramularia* leafspot than all other materials tested. Benomyl in southern California and thiophanate-methyl or benomyl in northern California gave the best leafspot control when fungicides applied as sprays after planting. Selecting leafspot free plants or obtaining plants from nurseries following a benomyl spray program prevented leafspot developing in fields in southern California. Most fungicides tested were either phytotoxic and/or gave ineffective control of leafspot.

## INTRODUCTION

In 1972, California produced 285 million pounds of strawberries on 7800 acres, with an average yield of 18.25 tons per acre. California produces 62% of strawberries in the United States with an average yield 8 times as great as the average of the rest of the United States combined. Plantings are made in both winter and summer. Winter plantings are from October to mid-November using plants from high elevation nurseries (3000 ft.) where plants receive some chilling before harvest. Fruit production may start on winter plantings 10 weeks after planting. Summer plantings are from early July to mid-September with planting stock harvested in December-January, packed in polyethylene and stored at -2°C until planting time. First fruit production is of little value and second fruiting response begins about 7 months after planting at the earliest. Production of the summer planting is usually at least double the volume per plant for the winter plantings.

Zineb and nabam + zinc-sulfate gave best control of *Mycosphaerella* while dichlone caused severe stunting and anilazine slight bronzing of leaves (Cox 1957). Horn (1961) burned strawberry foliage with dichlone and anilazine applied at higher concentrations. Maneb and copper oxychloride were more effective than zineb and ziram but the copper compound was slightly phytotoxic (Melac 1967). Bennett (1972) stated tetrachloroisophthalonitrile resulted in fewer malformed fruit than dichlofluanid although with more scorched calyces but benomyl had less malformed fruit and calyx damage.

Benomyl controlled Verticillium wilt when applied to the planting hole at planting time but was less effective when plant roots were dipped prior to planting

(Lockhart 1969). Jordan (1972) found one application of benomyl or thiabendazole to soil 24 hours before planting, dusting roots with formulated benomyl powder at planting, or a combination of both benomyl dust plus drench treatments were effective for Verticillium control.

Ramularia leafspot (Mycosphaerella fragariae) causes severe stunting of plants and reduces yields in California strawberry fields. Experiments reported herein compared fungicide dusts or dips of plants obtained from nurseries or fungicide sprays applied to plants after planting.

## METHODS AND MATERIALS

Preliminary Fungicide Trials 1969-1970. In early trials for the control of Ramularia leafspot, Botrytis storage rot, Rhizoctonia, etc. various fungicides either as plant dusts or dips were compared. Fungicides evaluated in these early trials included PCNB, benomyl, thiabendazole, captafol, chlorothalonil*, anilazine, thiram, dicloran, folpet, and dichlone. Summer plants harvested from the nursery in February were treated with fungicide, stored at -2°C, and rated in August before planting. Ratings were also made of these plants after planting in the lathhouse. Lathhouses are slatted structures open to the elements but provide some shade and wind control. Winter plants harvested from the nursery in October were treated with fungicides, and immediately planted in pots and placed on the lathhouse floor.

Benomyl dusts and dips were significantly better than all other materials for control of Ramularia leafspot and Botrytis storage mold and lack of phytotoxicity to roots and foliage of strawberry. Many materials tested were either ineffective for control of pathogens or were phytotoxic to roots and foliage in storage or after planting in the lathhouse. 'Tioga' and 'Fresno' varieties were more sensitive to effects of fungicides than 'Shasta'.

Fungicide Spray Trial 1970. 'Tioga' strawberry plants were winter planted two per 6-inch clay pot on November 1, 1969. The experiment was replicated five times with six pots per replicate. Plants were placed in a lathhouse and misted with water for 5 minutes every hour to enhance development of leafspot. Fungicides sprays were applied on January 19, February 2, 16, March 2, and 16. Rates (Table 1) are per 100 gal. of water and sprays applied for full coverage of plants. Disease index rating was made on March 23, 1970 on a scale of "0" to "5". A disease rating of "5" would mean the leaves were completely covered with lesions. Results are shown in Table 1.

Benomyl was significantly better than all other materials for the control of Ramularia leafspot. Captan, a standard commercial fungicide, provided relatively poor control. Captafol, while providing some control caused bronzing of foliage with repeated applications.

Southern California Dip Trial. Tioga strawberry nursery plants naturally infected with Ramularia were obtained from a high elevation commercial nursery in northern California. Plants were dipped for 5 minutes in the fungicide mixture and planted immediately in the field at South Coast Field Station, Santa Ana, California. Plots were replicated four times using 20 strawberry plants per replication.

*Suggested common name for tetrachloroisophthalonitrile

Sprinkler irrigation was used during the first 3 months of the leafspot trial. Additional plants from the dip treatments were planted in peat pots and placed in a lathhouse for observation. Results are shown in Table 2.

Table 1

Effect of fungicide sprays on control of Ramularia leafspot on Tioga strawberry, Santa Ana, California, USA. Winter-1970.

| Fungicide-Rate/100 gal. | Disease index March 23 |
|---|---|
| Benomyl 50 w.p. 8 oz. | 0.1 a* |
| Thiabendazole 60 w.p. 1 lb. | 0.7 b |
| Captafol 4F 1.5 qt. | 0.9 b |
| Chlorothalonil 75 w.p. 2 lb. | 1.1 b |
| Anilazine 50 w.p. 3 lb. | 1.6 c |
| Captan 50 w.p. 3 lb. | 2.1 d |
| Hexachlorophene 25% EC 0.5 pt. | 2.9 e |
| No treatment | 3.1 e |

*Means followed by the same letter are not significantly different at the 1% level, using Duncan's multiple range test.

Table 2

Effect of fungicides dips on control of Ramularia leafspot on Tioga strawberry, Santa Ana, California, USA. Winter-1972.

| Fungicide-Rate per 100 gal. | Field-No. leafspot/ 20 plants-Feb. 17 | Yield (g) | No. leafspot/20 plants (lathhouse, Mar. 1) |
|---|---|---|---|
| Thiophanate-methyl 70 w.p. 16 oz. | 0 a* | 412 a* | 6.5 |
| Benomyl 50 w.p. 4 oz. | 0 a | 399 a | 0 |
| Benomyl 50 w.p. 8 oz. | 0 a | 390 ab | 0 |
| Thiophanate-methyl 70 w.p. 8 oz. | 0 a | 381 ab | 0 |
| Benomyl 50 w.p. 16 oz. | 0 a | 372 abc | 0 |
| Captafol 4F 1 pt. | 201 b | 347 bcd | 79 |
| Captafol 4F 1 qt. | 185 b | 331 cd | 119 |
| No treatment | 480 c | 327 d | 149 |

*Means followed by the same letter are not significantly different at the 5% level, using Duncan's multiple range test.

Benomyl and thiophanate-methyl applied as a plant dip before planting provided excellent control of leafspot in both field and lathhouse. Yield was significantly increased with both benomyl and thiophanate-methyl. Captafol, both at 1 pt. and 1 qt., was phytotoxic to foliage in both field and lathhouse and control of leafspot and yield of strawberries with captafol was not significantly different from no treatment.

Northern California Trial. 'Tioga' strawberry nursery plants infected with *Ramularia* were obtained from a commercial high elevation nursery in northern California. Comparison was made between plants dipped in fungicides before planting versus fungicide sprays applied to foliage after planting. Possible control of other strawberry pathogens such as Rhizoctonia and Botrytis was also studied. Ten strawberry plants were used per plot and replicated four times. Plants were dipped for 5 minutes in the fungicide mixture on November 2, 1972 and immediately planted along with the other plants used for the fungicide spray treatments. Spray treatments were begun on November 9 and repeated at 14-day intervals throughout the growing season. Rohm and Haas B1956 spreader-sticker, 4 oz. per 100 gallons, was added to each foliage fungicide. Eight sprays were applied before leafspot data were taken on February 16, 1972.

Table 3

Fungicide dips vs. sprays for the control of Ramularia leafspot on Tioga strawberry, Watsonville, California, USA. Winter-1972.

| Fungicide-Rate per 100 gal. (Dips) | No. leafspot/ 10 plants February 16 |
|---|---|
| Thiophanate-methyl 70 w.p. 6 oz. | 0 a* |
| Thiophanate-methyl 70 w.p. 12 oz. | 0 a |
| Benomyl 50 w.p. 8 oz. | 0 a |
| Benomyl 50 w.p. 16 oz. | 0 a |
| (Sprays) | |
| Thiophanate-methyl 70 w.p. 12 oz. | 8 b |
| Thiophanate-methyl 70 w.p. 6 oz. | 12 b |
| Benomyl 50 w.p. 8 oz. | 15 bc |
| Benomyl 50 w.p. 16 oz. | 15 bc |
| Thiabendazole 60 w.p. 16 oz. | 22 c |
| Chlorothalonil 75 w.p. 1.5 lb. | 63 d |
| Zineb 25%, sulfur 20%, Cu 5% 3 lb. (Cosanil) | 86 e |
| 'Copper Count N' Cu 8% 2 pt. | 101 f |
| 'Castle Copper' 53% 1.5 lb. | 128 g |
| 'Copper Sorba' Cu 4% 2 qt. | 139 g |
| No treatment | 199 h |

*Data significant 1% level

Fungicide dips of thiophanate-methyl or benomyl applied at planting were significantly better than all other materials tested. Dipped plants were vigorous, and developed to at least twice the size of the control plants. There was a suggestion of control of other pathogens such as Rhizoctonia. Further, these same materials were significantly better than all others when applied as sprays. Chlorothalonil caused stunting, bronzing and russeting of sprayed leaves. Copper materials were generally ineffective.

Commercial Field Spray. Benomyl was applied to a commercial Tioga strawberry field near Santa Ana, California to evaluate its effectiveness as spray for control of Ramularia leafspot. Nursery plants were planted on November 1, 1971 in plots consisting of two single rows approximately 270 feet long and replicated four times. Treatments consisted of benomyl 50 w.p. 16 oz. per 100 gal. and a no treatment. Benomyl applications were made on November 15, December 10 and January 7 and leafspot counts were taken on January 14, 1972. Benomyl plots average 9.4 leafspots per 20 plants while controls averaged 214.4 leafspots.

Leafspot From Northern California Strawberry Nursery Fields. Ramularia leafspot is prevalent in some northern California strawberry nursery fields and consequently may be carried on transplants to commercial strawberry fields. Comparison was made at Santa Ana of plants obtained from; a nursery with benomyl fungicide spray applications; two nurseries where leafspot control was nil or inadequate; and from a nursery free of leafspot symptoms. Twenty Tioga strawberry plants were planted per plot on October 28, 1971 and replicated four times. Plots were sprinkle irrigated to enhance development of Ramularia leafspot. Ramularia leafspot was significantly reduced by applications of benomyl or selecting nursery stock free of leafspot symptoms as shown in Table 4.

Table 4

Ramularia leafspot development on transplants from four northern California nurseries - February 17, 1972.

| Treatments | No. leafspots/ 20 plants |
|---|---|
| No. 1-No visible leafspot | 0 a* |
| No. 2-Benomyl applied | 5 a |
| No. 3-Nil fungicide | 223 b |
| No. 4-Nil fungicide | 329 b |

*Significant 1% level

DISCUSSION

One of the limiting factors in these trials was the sensitivity of strawberry plants to various fungicides (see literature cited). Dicloran gave excellent control of Botrytis storage rot, but when these strawberry plants were planted produced stunting and necrosis of leaves. Likewise PCNB suggested as a strawberry plant dip in California was found to be phytotoxic to foliage and roots of strawberry. Chlorothalonil produced severe bronzing of leaves and stunting of plants when applied as sprays in the northern California trial.

Benomyl effectively controlled Ramularia leafspot in northern California nursery fields and continued to provide control of the disease when these plants were planted in southern California. Ramularia leafspot does not spread in commercially planted fields once the initial inoculum is eliminated. Research suggests that benomyl or thiophanate-methyl planting dips may even control Rhizoctonia crown and root rot. Increased vigor as well as yields of plants treated with thiophanate-methyl or benomyl were readily apparent in both southern and northern California trials.

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# EFFECTS OF BENZIMIDAZOLE COMPOUNDS AND OTHER FUNGICIDES ON LEAF SPOT OF BLACK CURRANT

F. Ó Ríordáin

The Agricultural Institute, Kinsealy Research Centre, Dublin 5.

Summary Dithianon and triforine gave better control of leaf spot (*Pseudopeziza ribis*) than mancozeb, which was used as a standard. Three benzimidazole fungicides, BAS 346 F, benomyl and thiophanate-methyl gave poor disease control in 1972 and 1973 in contrast to very good control in previous years.

Resumé L'utilisation du dithianon et de la triforine assure une protection plus efficace contre l'anthracnose (*Pseudopeziza ribis*) que le mancozèbe, utilisé comme témoin. Trois fongicides, BAS 346 F, le benomyl et le thiophanate-methyl se sont révélés peu efficaces en 1972 et 1973, malgré de bons résultats au cours des années précédantes.

## INTRODUCTION

Of the protectant fungicides tested against leaf spot (*Pseudopeziza ribis*) of black currants, mancozeb has been found one of the most satisfactory materials (Ó Ríordáin, 1968). In 1969 the systemic fungicide, benomyl, was first included in an experiment and it gave significantly better leaf spot control than mancozeb (Ó Ríordáin, 1969). Results with other systemic fungicides were reported in 1971 (Ó Ríordáin *et al*, 1971). This paper gives details of further results with these and other fungicides.

## METHOD AND MATERIALS

Two different experiments were carried out at the Soft Fruit Research Centre, Agricultural Institute, Clonroche, Co. Wexford. The layout of Experiment 1 has already been described (Ó Ríordáin *et al*, 1971). The fungicides and their rates of use are listed in Table 1. The fungicides were applied at 14 day intervals from bud burst with a self-propelled automatic sprayer, at 2246 l/ha and a minimum pressure of 11.9 at.

Experiment 2 was a comparison of benomyl and mancozeb, used at 0.6 and 2.7 kg/ha respectively. Spraying started at bud burst and was repeated at 14-day intervals. The cultivar was Wellington XXX. Plots consisted of two rows of closely planted bushes 18.3 m long and 2.7 m apart. The experiment was a randomised block design with five replications. Disease was assessed by the method of Clarke and Corke (1956). In this experiment ten readings, equally spaced along the rows, were made per plot. All other details are as already described (Ó Ríordáin, 1968; 1969; and Ó Ríordáin et al, 1971).

## RESULTS

In Experiment I in 1972 the three benzimidazole fungicides, carbendazin* (BAS 346 F), benomyl and thiophanate-methyl gave very poor control of leaf spot compared with mancozeb, which was used as the standard fungicide. Dithianon and triforine both gave significantly better disease control than the standard (Table I). Leaf spot developed late in this experiment in 1973. The benzimidazole fungicides again gave poor disease control. Best results were given by dithianon, mancozeb and triforine, with no significant differences between them (Table I).

Table I

Experiment I - Effects of six fungicides on leaf spot (%) of black currant, cultivar Wellington XXX

| | Kg a.i./ha | 1972 | | | | 1973 |
|---|---|---|---|---|---|---|
| Fungicide | per application | 3 July | 17 July | 17 Aug. | 14 Sept. | 19 Sept. |
| BAS 346 F | 0.6 | 20.5+++ | 46.0+++ | 89.2+++ | 97.0+++ | 22.0+++ |
| Benomyl | 0.6 | 18.2+++ | 33.8+++ | 86.7+++ | 97.5+++ | 19.9+++ |
| Dithianon | 1.3 | 3.5 | 4.2* | 28.6*** | 46.4*** | 1.0 |
| Mancozeb | 2.7 | 7.0 | 13.7 | 59.5 | 84.2 | 1.7 |
| Thiophanate-methyl | 1.2 | 12.7+ | 29.8+++ | 86.2+++ | 97.5+++ | 22.8+++ |
| Triforine | 0.6 | 4.6 | 5.8 | 43.2*** | 65.8*** | 1.3 |

*, **, *** – significantly better than mancozeb at 5%, 1% and 0.1%

+, ++, +++ - significantly worse than mancozeb at 5%, 1% and 0.1%

Benomyl and mancozeb did not differ significantly in disease levels in Experiment 2 the first year (Table 2). But in 1972 and in 1973 benomyl gave significantly worse leaf spot control than mancozeb.

*proposed common name for methyl benzimidazol-2-yl carbamate

Table 2

Experiment 2 - Effects of benomyl and mancozeb from bud burst on leaf spot (%) of black currant, cultivar Wellington XXX

| Fungicide | 1971 | | | 1972 | | | | 1973 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 9 Aug. | 10 Sept. | 12 Oct. | 3 July | 17 July | 17 Aug. | 14 Sept. | 27 July | 22 Aug. | 19 Sept. |
| Benomyl | 1.3a* | 18.0a | 27.1a | 9.1b | 37.4b | 89.7b | 97.2b | 7.6b | 49.9b | 91.3b |
| Mancozeb | 2.6a | 24.0a | 34.8a | 1.6a | 4.1a | 35.3a | 71.8a | 0.5a | 7.8a | 19.4a |

*Values followed by a common letter do not differ significantly at the 0.1% level

## DISCUSSION

In the experiments carried out at the Soft Fruit Research Centre up to the 1971 season the systemic fungicides, benomyl and triforine, gave better control of leaf spot than all the other fungicides tested except dithianon (Ó Ríordáin, 1969 and Ó Ríordáin et al, 1971). In 1971, thiophanate-methyl was not as effective as benomyl but similar in performance to the standard mancozeb (Ó Ríordáin, 1971). This order of effectiveness of the two benzimidazole fungicides is the same as that obtained in Poland (Borecki et al, 1971). The 1972 and 1973 results were radically different. Benomyl, and the two other benzimidazole fungicides tested, BAS 346 F and thiophanate-methyl, which did not differ significantly from each other, gave significantly worse leaf spot control than mancozeb. Dithianon and triforine were the only fungicides tested that gave a significant improvement in disease control over that of mancozeb in 1972. The relative performances of benomyl and mancozeb also changed in Experiment 2 over the three years. In 1971 they gave similar results, but in 1972 and 1973, benomyl gave significantly worse leaf spot control than mancozeb.

A possible explanation for the variable performance of the benzimidazole fungicides may be found in the different weather patterns of the years concerned. The springs of the years 1969 to 1971 were relatively dry and calm, while those of 1972 and 1973 were wetter and had much stronger winds (Table 3). Although this needs much closer examination it may be that benzimidazole fungicides are not as effective under these latter conditions.

Table 3

Wind and rainfall records, Co. Wexford, April and May 1969 to 1973

| Year | April | | May | |
|---|---|---|---|---|
| | Wind* | Rainfall mm | Wind* | Rainfall mm |
| 1969 | 39 | 42 | 11 | 111 |
| 1970 | 63 | 69 | 15 | 8 |
| 1971 | 40 | 53 | 3 | 62 |
| 1972 | 92 | 59 | 114 | 120 |
| 1973 | 85 | 39 | 27 | 136 |

*Duration in hours of wind over 21 knots

A further possibility is the development of a strain of the pathogen resistant to these fungicides (Bollen and Scholten, 1971). This is considered unlikely as the change in efficiency of these fungicides occurred abruptly, the full extent of the change occurred from 1971 to 1972, and it was uniform in two widely separated experiments.

In view of the good control of many different diseases generally got with these fungicides it is of importance to understand the reasons for their failure in the 1972 and 1973 seasons. If climatic factors are found to be critical, a spray programme including two or more fungicides might be drawn up taking into consideration the optimum conditions for a particular fungicide and the needs of the crop.


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# CONTROL OF RASPBERRY DISEASES WITH THIOPHANATE-METHYL

R.J.Cole & T.W.Cox

May & Baker Ltd., Ongar Research Station, Essex

Summary In both replicated and grower trials carried out during 1972 and 1973, thiophanate-methyl gave excellent control of grey mould (Botrytis cinerea), spur blight (Didymella applanata) and cane spot (Elsinoe veneta) on raspberries at a dose rate of 1 lb a.i. per acre.

A total of 11 experiments were conducted in Kent with a further 14 grower trials in Scotland. Grey mould tolerance to benzimidazole fungicides was recorded in 1972 at one site in Kent.

No phytotoxicity was observed on the six varieties sprayed and samples of fruit treated at twice the normal dose rate showed no taint or off-flavour when processed (canned, quick frozen and jam).

Sommaire Dans les essais repliqué et en champs effectués au cour des années 1972 et 1973, le méthylthiophanate a été tres efficace contre la pourriture grise, le brûlure des dards, l'anthracnose du framboisier sur framboisiers à raison de 1 lb m.a./ac (dose normale).

Onze essais repliqués ont été realisés dans le Kent et quatorze essais sur champs en Ecosse. Une resistance de la maladie B.cinerea a été noté dans un verger dans le Kent en 1972.

Aucune action phytotoxique n'a été observée sur les six varietés de framboises et les fruits traitées à dose double, et utilisés pour confiture, gêlée etc., et la saveur de ces fruits n'a pas été altéré.

## INTRODUCTION

The success of thiophanate-methyl against a wide range of diseases on other soft fruits (Gilchrist & Cole, 1971) led to a series of replicated trials being carried out on raspberries in 1972. For ease of working, most of the detailed sites were located in Kent, although three trials were carried out in Scotland in 1972 and a further 11 grower trials in Scotland and three in Kent in 1973.

In addition to the efficacy trials, samples of fruit were also treated for residue and taint testing purposes.

## METHODS AND MATERIALS

The replicated trials in Kent were sprayed using hand lance equipment at 200 gal/ac. Plot sizes were of single or double rows of between 25-60 ft. Four replicates were generally used and major commercial varieties were treated. Spraying commenced at ¼ in. green bud and applications were repeated at 14 day intervals, reducing in some instances to 10 day intervals over the flowering period (usually six or seven applications in total). Treatments involved four doses of thiophanate-methyl, one with wetter; two commercial standards and an unsprayed control.

Grower trial recommendations were to apply three sprays of thiophanate-methyl using 2 lb of the commercial 50% wettable powder formulation commencing at 10% flowering and repeating at 10-14 day intervals and to compare disease control with that given by standard commercial fungicides used at their recommended dose rates. Applications were made through growers' own sprayers and volumes ranged from 100-250 gal/ac.

Assessment of grey mould on the berries was carried out at harvest. Samples of fruit (usually 200-1000 berries per treatment) were picked and stored until grey mould became evident. Storage varied between refrigerated (8°C) and ambient (c.18°C) conditions. Percentage infected fruit was then assessed, and in the case of the grower trials, assessments were made at regular intervals post-picking. At some sites, growers also made their own assessments (see Table 6).

Spur blight causes a typical pale lesion around the buds of the new canes which turns silver as the cane hardens. Black pycnidia can be seen on this silvered area. The total number of buds so affected on each of 40 canes per treatment were recorded during the dormant period following spraying. Cane spot is typified by small sunken lesions surrounded by a darker (purple/brown) area during cane dormancy. Total area of cane so affected was measured using 40 canes per treatment and a mean value is given in the results.

Fruit yields were recorded in the 1973 trials by picking entire plots over the season and extrapolating these data to cwt/acre.

## RESULTS

Both replicated and user trial results from 1972 and 1973 are presented in the following tables.

## Table 1

### Control of grey mould - Replicated trials (1972)

| Treatment & dose rate (a.i./ac.) | | Percent infected berries Site 1 | Site 2 | Site 3* | Site 4 | Site 5 | Site 6 | Site 7 | Site 8 |
|---|---|---|---|---|---|---|---|---|---|
| thiophanate-methyl | ¾ lb | 4.5 | 3.8 | 17.1 | 14.5 | 3.0 | - | - | - |
| thiophanate-methyl | 1 lb | 4.8 | 1.5 | 15.8 | 8.0 | 1.0 | 0.0 | 6.0 | 2.0 |
| thiophanate-methyl | 1½lb | 3.0 | 2.0 | 17.1 | 4.0 | 2.5 | - | - | - |
| thiophanate-methyl + wetter | 1 lb | 5.0 | 2.8 | 17.9 | 7.5 | 1.0 | - | - | - |
| benomyl | ½ lb | 6.3 | 3.0 | 9.8 | 19.5 | 2.0 | 1.5 | 19.0 | 3.4 |
| dichlofluanid | 2 lb | 18.5 | 5.5 | 4.1 | 21.5 | 0.0 | 0.0 | 14.0 | 0.5 |
| control | - | 85.0 | 33.8 | 23.2 | 44.0 | 25.5 | 15.0 | 41.0 | 25.0 |
| Storage conditions - days | | 2 | 3 | 0 | 3 | 3 | 8 | 8 | 7 |
| | temp.°C | 18° | 18° | - | 18° | 18° | 8° | 8° | 8° |
| Variety | | MP | ME | MJ | ME | NG | MJ | MJ | MJ |

MP = Malling Promise
ME = " Exploit
MJ = " Jewel
NG = Norfolk Giant

* Disease resistance confirmed by Laboratory tests.

Table 2

Control of grey mould - Grower Trials (1973)

| Site | Treatment | Percent rotted fruit (days after picking): 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Tibbermore | thiophanate-methyl | 9 | 15 | 45 | 83 | - | - |
| | benomyl | 5 | 10 | 31 | 63 | - | - |
| Kinrossie | thiophanate-methyl | 1 | 2 | 23 | 46 | 64 | 96 |
| | dichlofluanid | 0 | 1 | 9 | 18 | 46 | 88 |
| Alyth | thiophanate-methyl | 2 | 6 | 31 | 69 | 92 | - |
| | benomyl | 0 | 2 | 26 | 66 | 91 | - |
| | untreated | 15 | 46 | 74 | 98 | - | - |
| Blairgowrie 1. | thiophanate-methyl | 11 | 17 | 46 | 89 | - | - |
| | benomyl | 13 | 26 | 62 | 84 | - | - |
| Blairgowrie 2. | thiophanate-methyl | 1 | 1 | 16 | 37 | 79 | - |
| | thiram(2)/benomyl(1) | 11 | 18 | 52 | 87 | - | - |
| Blairgowrie 3. | thiophanate-methyl | 16 | 52 | 85 | - | - | - |
| | benomyl | 29 | 70 | 87 | - | - | - |
| | dichlofluanid | 38 | 66 | 96 | - | - | - |
| | carbendazim * | 19 | 48 | 80 | - | - | - |
| Dundee | thiophanate-methyl | 1 | 2 | 10 | 44 | 90 | - |
| | benomyl | 1 | 3 | 22 | 46 | 77 | - |
| | dichlofluanid | 1 | 2 | 15 | 43 | 92 | - |
| | carbendazim * | 1 | 3 | 27 | 63 | 94 | - |
| Inchture 1. | thiophanate-methyl | - | 66 | - | - | - | - |
| | benomyl | - | 68 | - | - | - | - |
| Inchture 2. | thiophanate-methyl | - | 58 | - | - | - | - |
| | benomyl | - | 63 | - | - | - | - |
| Maidstone | thiophanate-methyl | 2 | 9 | 16) Mean of 4 picks | | | |
| | dichlofluanid | 3 | 11 | 19) | | | |
| Canterbury | thiophanate-methyl | 1 | 5 | 22) Mean of 6 picks | | | |
| | benomyl | 1 | 4 | 23) | | | |

Fruit stored at ambient temperature in all cases.

* Carbendazim is the suggested common name for methyl benzimidazol-2-yl carbamate, the formulation used being 60% wettable powder.

Table 3

Control of raspberry cane diseases - Replicated trials (1972)

| Treatment & dose rate (a.i./acre) | | SPUR BLIGHT Mean No. infected buds/cane Site 72/1 | Site 72/2 | Site 72/3 | Site 72/4 | Site 72/5 | CANE SPOT Mean length (inches) of infected area/cane Site 72/2 |
|---|---|---|---|---|---|---|---|
| thiophanate-methyl | ¾ lb | 5.6 | 2.3 | 1.8 | 2.8 | 0.9 | 18.7 |
| thiophanate-methyl | 1 lb | 5.2 | 0.6 | 1.3 | 2.1 | 0.7 | 15.0 |
| thiophanate-methyl | 1½lb | 4.2 | 0.8 | 1.9 | 2.2 | 0.8 | 9.5 |
| thiophanate-methyl + wetter | 1 lb | 4.5 | 1.0 | 1.6 | 2.1 | 0.4 | 16.5 |
| benomyl | ½ lb | 7.1 | 2.3 | 1.5 | 2.6 | 0.9 | 14.2 |
| dichlofluanid | 2 lb | 5.2 | 1.3 | 1.3 | 4.1 | 0.8 | 17.2 |
| Control | - | 10.1 | 4.7 | 3.1 | 6.5 | 2.6 | 35.0 |

## Table 4

Yield of marketable fruit - replicated and user trials (1973)

| Treatment and dose rate (a.i./acre) | | Weight marketable fruit - cwt/acre Site 73/1 | Site 73/2 | Site 73/3 | Preston | Canterbury |
|---|---|---|---|---|---|---|
| thiophanate-methyl | 1 lb | 79.0 | 65.7 | 72.4 | 55.5 | 82.5 |
| dichlofluanid | 2 lb | 74.8 | 54.7 | 83.3 | 56.6 | 86.1 (benomyl) |
| control | - | 68.6 | 39.0 | 66.7 | - | - |
| Variety | | Glen Clova | Malling Jewel | Malling Jewel | Malling Jewel | Malling Jewel |

## Table 5

Shelf life study - Grower assessments

| Site | Treatment | No. days remaining marketable 1st pick | 2nd pick | 3rd pick | 4th pick |
|---|---|---|---|---|---|
| Kinrossie | thiophanate-methyl | 5 | 2 | 3 | 3 |
| | dichlofluanid | 4 | 2 | 3 | 3 |
| Tibbermore | thiophanate-methyl | 2 | 2 | 3 | - |
| | benomyl | 3 | 2 | 3 | - |
| Alyth | thiophanate-methyl | 5 | - | - | - |
| | benomyl | 5 | - | - | - |
| | untreated | 1 | - | - | - |
| Blairgowrie 1 | thiophanate-methyl | 3 | - | - | - |
| | benomyl | 3 | - | - | - |
| Blairgowrie 2 | thiophanate-methyl | 2.2) | Mean of 10 picks | | |
| | thiram(2)/benomyl(1) | 2.0) | | | |
| Caputh (1972) | thiophanate-methyl | 4.4) | Mean of 24 picks | | |
| | benomyl | 4.3) | | | |
| | dichlofluanid | 4.2) | | | |
| | unsprayed | 2.2) | | | |

## DISCUSSION

In general, excellent control of grey mould was achieved with applications of thiophanate-methyl over the flowering period (Table 1). At Site 3 in the 1972 replicated trials, disease tolerance was encountered however. This was on a holding where the grower had used benomyl for two successive seasons, up to seven applications per season for the control of cane diseases. Cross-resistance to thiophanate-methyl was evident, but not to dichlofluanid. Optimum disease control was given by 1 lb a.i. thiophanate-methyl per acre, this being equal or superior to standard materials (save at Site 3). These results were confirmed in the grower trials (Table 2 and Table 5) where thiophanate-methyl at 1 lb a.i./acre gave equivalent control to dichlofluanid and benomyl, and superior control to a thiram (2 sprays)/benomyl (1 spray) mixed programme. Furthermore, the benefit from spraying is clearly demonstrated in the extended shelf-life of the berries. This obviously gives the grower greater flexibility in arranging transport etc., for this extremely perishable crop.

Late season (i.e. December/January) assessments of spur blight showed that low-medium levels of infection on five sites were well controlled by thiophanate-methyl at 1 lb a.i./acre, equivalent or slightly superior to that given by standard materials (Table 3). An infection of cane spot on one site in Kent was similarly well controlled.

Yield trials (Table 4) in 1973 (a severe year for grey mould) showed that three sprays of 1 lb a.i./acre thiophanate-methyl applied over the flowering period considerably increased yields of clean fruit over unsprayed controls (20-40% increase).

Samples of raspberries treated with 2 lb a.i./acre thiophanate-methyl (i.e. twice the normal dose) were submitted to the Campden Food Preservation Research Association (for canning and quick frozen taint tests) and to the British Food Manufacturing Industries Research Association (for jam taint tests) in 1972 and 1973. No taints or off-flavours from raspberries so treated and subsequently processed have been recorded to date.

The use of thiophanate-methyl on raspberries (up to six applications per season) has received Full Commercial clearance under the terms of the Pesticides Safety Precautions Scheme.

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Proceedings 7th British Insecticide and Fungicide Conference (1973)

# FIELD EVALUATION OF CARBENDAZIM (BAS 346F)
# AS A FUNGICIDE IN SOFT FRUIT

W. H. Phillips
BASF United Kingdom Ltd., Lady Lane, Hadleigh, IP7 6BQ, Suffolk
G. A. V. Ellis and J. Merryweather
Fisons Ltd., Chesterford Park Research Station, Nr. Saffron Walden, Essex

Summary Carbendazim was applied at 0.025%, 0.035% and 0.05% a.i. at 14 day intervals to blackcurrants, gooseberries, strawberries and raspberries. Sites were chosen in East Anglia and the South-West of England on commercial crops and where possible on sites where the disease incidence was expected to be severe. Good control of the major soft fruit diseases was achieved, being comparable to that of benomyl. No phytotoxicity was recorded at any time with rates up to 0.05% a.i. Strawberries grown under cloches and polythene tunnels were also treated and no damage occurred.

Résumé Le carbendazim a été appliqué à 0.025%, à 0.035% et à 0.05% m.a. à 14 jours d'intervalle sur cassis, groseilles, fraises et framboises. Les lieux ont été choisis dans l'East Anglia et dans le Sud-Ouest de l'Angleterre sur des cultures commerciales et dans les endroits possibles ou l'on esperait une incidence severe de la maladie. Un bon contrôle de la plupart des maladies des petits fruits a été obtenu, tout comme avec le benomyl. Aucune phytotoxicité n'a été enregistrée à aucun moment, même avec des doses de 0.05% m.a. Les fraisiers cultives sous cloches et sous tunnels de polyethylene ont été aussi traités et aucun dommage ne s'est manifesté.

## INTRODUCTION

Carbendazim is the suggested common name for methyl benzimidazol-2-yl carbamate (MBC). It is a broad-spectrum fungicide of the benzimidazole group, developed in the laboratories of BASF Aktiengesellschaft, Ludwigshafen, Germany. In the United Kingdom the product is being developed jointly by BASF U.K. Ltd., and Fisons Ltd., for use on a wide range of crops. Tapley et al (1969) reported results obtained with benomyl where it was shown that this compound could replace more complex spray programmes commonly used in soft fruit. During 1972 and 1973 the authors have carried out a number of trials to demonstrate the activity of carbendazim against fungal diseases of soft fruit. In all cases benomyl was used as a standard comparison. Other materials were included where appropriate; in the blackcurrants and gooseberry trials a combination of zineb, quinomethionate and dichlofluanid was used, and in the strawberry trials, dichlofluanid.

## METHOD AND MATERIALS

A 50% wettable powder formulation of carbendazim was used, which has the code number BAS 3460F. All applications were made at high volume with a mist blower or a hand lance applicator and the foliage was sprayed to run-off (approx. 2000-2500 l/ha). The trials were of randomised block design with 4 to 5 replicates.

Blackcurrants and gooseberries

Replicated trials were carried out in East Anglia and the West Midlands. Plot sizes varied, but were never less than 4 bushes. One trial was carried out on a non-bearing blackcurrant crop. A programme of three sprays was applied in the gooseberry trials commencing at early flower; the blackcurrants received four sprays, the first being applied at the 'grape' stage. The varieties treated were:- Blackcurrants - Baldwin, Gooseberries - Careless. Other varieties have been treated in commercial applications. A taint test programme on blackcurrants and gooseberries has been completed and no taint was recorded. Yields were assessed by hand picking, except in one case where a 'Bruff' stationary harvester was used. Leaf spot was assessed by the Clarke & Corke (1956) method. Mildew was assessed either on a 0-10 scale which was related to percentage value or by recording the percentage leaves infected on the new growth.

Strawberries and raspberries

Trials have been carried out on strawberries in East Anglia in 1972 and 1973. Two trials on raspberries have been carried out in 1973. The trials have been primarily aimed at grey mould control and quantative assessments of this disease only are available. Plot size varied, but was never less than 5 metres of row. Healthy and diseased fruit were separated at harvest, and the respective yields are given in the tabulated results. The following varieties of strawberries have been treated:- Cambridge Favourite and Prize-winner, Merton Princess and Red Gauntlet. Raspberry varieties treated were Norfolk Giant and Malling Jewel. The variety Glen Clova was also treated commercially. A programme of taint testing has been completed on strawberries and no taints have been recorded in treated fruit. A taint testing programme for raspberries is in progress and should be completed by 1975.

## RESULTS

Blackcurrants and Gooseberries

Powdery mildew - (Sphaerotheca mors-uvae) In general mildew tended to develop late in the season and was not present in appreciable amounts until shortly before harvest. By this time the last spray had been applied for some weeks. In all trials where the disease was recorded it appeared initially in the untreated areas but later was seen throughout the trial, but developing less rapidly in treated plots. On treated bushes the disease was mainly concentrated on the new growth and since the last applications were made sometime previously (14-28 days) it may be assumed that these shoots were not fully protected.

## Table 1

### The effect of carbendazim on powdery mildew of blackcurrants and gooseberries

% foliar mildew 1972

| Treatments & conc$^n$ a.i. | Blackcurrants Site A | Site B | Site C | Site D | Gooseberries Site G |
|---|---|---|---|---|---|
| Untreated | 49.0 | 18.4 | 98.0 | 41.75 | 44.0 |
| carbendazim 0.025% | 13.5 | 12.8 | 41.7 | 23.5 | 21.25 |
| carbendazim 0.035% | 13.5 | 12.8 | 45.7 | 21.25 | 20.25 |
| benomyl 0.025% | 20.0 | 17.2 | 44.7 | 18.25 | 17.25 |
| quinomethionate 0.75% | 10.0 | 10.0 | 43.7 | - | - |
| Date assessed | 8.8. | 13.9. | 11.8. | 4.9.* | 18.7.* |

* post-harvest sprays applied

## Table 2

### The effect of carbendazim on powdery mildew of blackcurrants and gooseberries

% fruit mildew 1972

| Treatments & conc$^n$ a.i. | Gooseberries Site E | Site G |
|---|---|---|
| Untreated | 20.0 | 85.5 |
| carbendazim 0.025% | 0.5 | nil |
| carbendazim 0.035% | 0.4 | nil |
| benomyl 0.025% | 0.5 | nil |
| quinomethionate 0.75% | 8.3 | - |
| Assessed | at harvest | |

In many cases the individual bush assessments varied considerably, but overall good control was achieved with carbendazim being on average comparable to benomyl but somewhat less effective than quinomethionate. Post-harvest sprays of carbendazim applied to an existing mildew infection were effective in reducing the level considerably. At two gooseberry sites where mildew developed on the fruit, carbendazim and benomyl kept the fruit virtually free from mildew throughout, although mildew was developing on the foliage. Mildew did however develop on the fruit in the quinomethionate treated plots.

Leaf spot - (*Pseudopeziza ribis*) Incidence of leaf spot was generally severe in 1972. Despite its severity, the attack was comparatively late and as such had little effect on yield. Defoliation in the untreated plots was below 20% in all trials at harvest, but by late July - (gooseberries), mid-August - (blackcurrants) defoliation was almost total.

Table 3

The effect of carbendazim on leaf spot of blackcurrants and gooseberries

% leaf spot 1972

| Treatments and conc$^n$ a.i. | Blackcurrants Site B | Site J | Site A | Site H | Gooseberries Site E | Site G |
|---|---|---|---|---|---|---|
| Untreated | 100 | 100 | 100 | 30.60 | 98.00 | 21.00 |
| carbendazim 0.025% | 0 | 0 | 0 | 0 | 15.00 | 0 |
| carbendazim 0.035% | 0 | 0 | 0 | 0 | 12.20 | 0 |
| benomyl 0.025% | 0 | 0 | 0 | 0 | 7.80 | 0 |
| zineb 0.14% | 6.25 | 0 | 27.78 | 0 | 39.30 | 0 |
| Date assessed | 13.9. | 11.8. | 8.8. | 31.7. | 14.8. | 18.7. |

The trials show that carbendazim and benomyl gave excellent control of leaf spot. Zineb was, however, somewhat less effective.

Grey mould - (*Botrytis cinerea*) In 1972 grey mould was not particularly prevalent in soft fruit crops and was only recorded at one site. In 1973, however, the disease was more widespread.

In blackcurrants moderate levels of grey mould were recorded in the untreated areas at harvest.

Table 4

The effect of carbendazim on grey mould of blackcurrants and gooseberries

% grey mould infection 1972 and 1973

| Treatments and conc$^{n}$ a.i. | Blackcurrants Site H | Blackcurrants Site K | Gooseberries Site L |
|---|---|---|---|
| Untreated | 10.60 | 15.40 | 60.00 |
| carbendazim 0.025% | 0.56 | 0.25 | 1.50 |
| carbendazim 0.035% | 0.44 | 0 | 0 |
| carbendazim 0.05% | 0 | 0.05 | 1.00 |
| benomyl 0.025% | 0.64 | 0.13 | 1.00 |
| Date assessed | 31.7. | 18.7. | after 2 weeks storage |

Carbendazim and benomyl gave very good control showing less than 1% infection.

Grey mould was not recorded on gooseberries at harvest, but when samples were stored the disease developed relatively quickly in untreated fruit.

## Yield

Yield assessments have been carried out on the majority of the trials and despite the fact that a marked yield response has been obtained, none of these differences was significant.

Table 5

The effect of carbendazim

on the yield of blackcurrants and gooseberries

(results expressed as plot means in Kg)

| Treatments and conc$^{n}$ a.i. | Blackcurrants | | | | | Gooseberries | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Site A | Site B | Site J | Site H | Site D | Site E | Site F | Site G | Site M |
| untreated | 18.39 | 15.45 | 50.40 | 6.28 | 13.05 | 27.65 | 4.87 | 10.60 | 17.40 |
| carbendazim 0.025% | 20.04 | 20.87 | 45.00 | 9.90 | 18.03 | 30.15 | 5.23 | 11.60 | 15.40 |
| carbendazim 0.035% | 21.91 | 21.70 | 56.40 | 7.53 | 21.05 | 30.27 | 6.56 | 11.90 | 13.30 |
| benomyl 0.025% | 20.95 | 18.66 | 54.90 | 9.08 | 21.23 | 32.71 | 5.25 | 11.30 | 13.80 |
| zineb 0.14%<br>quinomethionate 0.75%<br>dichlofluanid 0.1% | 20.63 | 22.60 | 55.20 | - | - | 27.21 | 5.09 | - | - |
| | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. |

There is in these results, however, a distinct upward trend, and the lack of significance is likely to be due to the tremendous variation between bushes which has not been overcome by replication.

Strawberries and Raspberries

Grey mould - (Botrytis cinerea) Eight replicated trials have been carried out in East Anglia in 1972 and 1973. Grey mould was recorded at all sites but was particularly severe in 1973. Moderate levels of the disease were also present at the two East Anglian raspberry sites.

Table 6

The effect of carbendazim on the yield of strawberries 1972

(results expressed as plot means in Kg)

| Treatments and conc$^n$ a.i. | Site A | | Site B | | Site C | |
|---|---|---|---|---|---|---|
| | Yield | No. of infected fruit | Yield | No. of infected fruit | Yield | Yield of infected fruit |
| untreated | 10.82 | 112 | 12.85 | 399 | 4.66 | 0.96 |
| carbendazim 0.025% | 10.22 | 43 | 16.69 | 221 | 7.12 | 0.49 |
| carbendazim 0.035% | - | - | - | - | 5.50 | 0.30 |
| carbendazim 0.05% | 12.53 | 50 | 17.27 | 158 | - | - |
| benomyl 0.025% | 11.23 | 44 | 16.19 | 221 | 6.67 | 0.49 |
| | not significant | | LSD at 5% = 1.11, 1% = 1.60, 0.1% = 2.35 | | LSD at 5% = 0.38, 1% = 0.52, 0.1% = 0.71 | not significant |

Table 7

The effect of carbendazim on the yield of strawberries 1973

(results expressed as plot means in Kg)

| Treatments and conc$^{n}$ a.i. | Site D | | Site E | | Site F | | Site G | |
|---|---|---|---|---|---|---|---|---|
| untreated | 7.84 | 1.08 | 5.53 | 3.00 | 1.11 | 0.48 | 2.71 | 0.93 |
| carbendazim 0.025% | 9.01 | 0.58 | 7.93 | 0.48 | 1.47 | 0.21 | 4.82 | 0.46 |
| carbendazim 0.035% | - | - | - | - | 1.94 | 0.32 | 4.87 | 0.39 |
| carbendazim 0.05% | 9.31 | 0.67 | 8.05 | 0.41 | - | - | - | - |
| benomyl 0.025% | 9.16 | 1.11 | 7.10 | 0.61 | 1.55 | 0.21 | 5.05 | 0.63 |
| dichlofluanid 0.1% | - | - | - | - | 1.14 | 0.15 | 4.97 | 0.28 |
| LSD at 5% | N.S. | 0.45 | 1.66 | 1.14 | N.S. | N.S. | 0.34 | N.S. |
| 1% | | | | 1.64 | | | 0.53 | |
| 0.1% | | | | | | | 0.89 | |

Table 8

The effect of carbendazim on the yield of raspberries 1973

(results expressed as plot means in Kg)

| Treatments and conc$^n$ a.i. | Site H | | Site J | |
|---|---|---|---|---|
| Untreated | 4.13 | 0.23 | 11.43 | 1.03 |
| carbendazim 0.025% | 5.48 | 0.02 | 13.26 | 0.59 |
| carbendazim 0.05% | 5.73 | 0.02 | 12.93 | 0.54 |
| benomyl 0.025% | 4.68 | 0.02 | 13.42 | 0.55 |
| LSD at 5% | N.S. | 0.11 | N.S. | 0.31 |
| 1% | | 0.16 | | |

The disease was well controlled by carbendazim, benomyl and dichlofluanid. Despite higher disease incidence in 1973, control in that year was generally better. This may be due to shorter flower period which occurred in 1973. The cold weather during May of 1972 tended to extend the flowering period and this made spray timing more difficult. Where later pickings were delayed by heavy rain, the disease tended to spread rapidly in untreated plots and low to moderate levels developed in treated areas. In 1973 some incidence of Rhyzopus nigricans was also observed but levels did not appear to vary between treated and untreated plots.

Yield increases were consistently obtained with all treatments. Carbendazim and benomyl gave similar increases, being somewhat greater than those obtained with dichlofluanid. Fruit treated with carbendazim and benomyl also appeared to have a better finish than those treated with dichlofluanid.

## DISCUSSION

The results presented in this paper show that carbendazim at 0.025% a.i. has given very good control of the major soft fruit diseases when applied at 14-day intervals during the critical infection periods of the specific fungi. The use of higher rates, although occasionally giving marginally higher yields, did not generally give better disease control. There is therefore no apparent justification in using higher rates. Carbendazim has compared equally with benomyl throughout and their range of activities appear similar. There are indications that the programmes used could be supplemented by additional sprays later in the season for the control of mildew in blackcurrants and gooseberries and grey mould of strawberries under conditions of severe disease incidence.

Commercial applications have been made during 1972 to all the soft fruit crops mentioned in this report. Mixtures with commonly used insecticides have been applied and no compatibility problems have been reported.

## References


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