Side-Effects of Downy Mildew Fungicides on the Incidence of Hop Powdery Mildew (*Sphaerotheca humuli*)

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SUMMARY

In a trial on 10 acres (4 ha) of hops in 1972, three downy mildew fungicides were superimposed on to a routine dinocap schedule and compared for their effects on powdery mildew control. Both mildew diseases built up to fairly high levels between the last spray applications and harvest. Copper oxychloride was significantly superior to zineb in restricting development of powdery mildew in hop cones while propineb appeared to be only slightly inferior to copper. There were no differences between fungicides for control of downy mildew.

Cone yield was significantly correlated with the amount of downy mildew, but not of powdery mildew, at harvest.

INTRODUCTION

During the last decade English hop growers have experienced increasing difficulty in controlling powdery mildew (*Sphaerotheca humuli* (DC.) Burr.) with routine dinocap/sulphur fungicide programmes, especially in the highly susceptible and widely-grown cultivar, Northern Brewer. Recent attacks of powdery mildew both in this country and Germany (Wiedemann, 1972) have been particularly severe, and as a result growers have on occasion been compelled to abandon a proportion of their crop. This increasing importance of powdery mildew has coincided with, and been attributed to, both the gradual decline in the use of copper-based fungicides in favour of organic materials (e.g. zineb, polyram) for control of downy mildew (*Pseudoperonospora humuli* (Miy. & Tak.) Wilson) and to changes in certain cultural practices, particularly that of replacing cultivations with herbicides for weed control. A similar situation has been encountered with American gooseberry mildew (*Sphaerotheca morus-uvae*) on black currants (R. J. W. Byrde, pers. comm.).

Although Horsfall and Lukens (1966) have reflected the feelings of several workers that dithiocarbamate fungicides allow more severe attacks of powdery mildews, there is little quantitative evidence in support of this view (Hislop and Cox, 1969). Both Aerts and Soenen (1957) and Moore (1966) showed that organic materials were inferior to copper in controlling apple powdery mildew (*Podosphaera leucotricha*); and, in a preliminary test with potted hop plants in a glasshouse, Royle (1969) reported greater development of powdery mildew on leaves treated with polyram than with copper, cufraneb giving an intermediate level of infection.

Copper fungicides have fallen out of favour with hop growers mainly because of their tendency to induce phytotoxicity and, more recently, because of high

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cost. In view of the current seriousness of powdery mildew and the continued 
decline in the use of copper (Umpelby and Sly, 1972) a large-scale trial, on a 
site with a recent history of bad powdery and downy mildew attacks, was 
conducted in 1972 to examine the effects, on powdery mildew incidence, of 
superimposing copper or zineb sprays on to a routine dinocap programme. The 
downy mildew fungicide propineb was also included since it is increasing in 
popularity amongst hop growers (Umpelby and Sly, 1972) and like copper it 
has been claimed to have beneficial side-effects against powdery mildews of hop 

MATERIALS AND METHODS

Arrangement of the trial

The trial was in a garden of 10 acres (4 ha) in which herbicides were employed 
for weed control and three susceptible cultivars, Northern Brewer, Eastwell 
Golding and Cobbs (a Golding cultivar), were grown separately. The crop was 
produced seedless, in the absence of male plants, so yields were expected to be 
lower than when seeded. There were four blocks within each of which three 
treatments were randomised. Each treatment plot was 9–12 rows wide and its 
length occupied the width of the garden (60–80 plants). Unfortunately it was 
not possible to distribute the treatments uniformly amongst the cultivars 
because a minimum plot width was necessary to obviate the effects of spray 

drift (Table 2).

The treatment fungicides were copper oxychloride, (45 per cent copper), 
zineb w.p. (70 per cent formulation), and propineb w.p., (70 per cent formulation). 
All plots received two applications of streptomycin (17 per cent formulation) 
in the early season and a generous powdery mildew control programme of 
dinocap e.c. (50 per cent formulation). The complete fungicide schedule is 
shown in Table 1. Magnesium sulphate (10lb/acre (11.2kg/ha)) was applied 
twice and urea (5lb/acre (5.6kg/ha)) once during the season. Aphids were con-
trolled adequately with either organophosphorus or carbamate insecticides.

<table>
<thead>
<tr>
<th>Date</th>
<th>No. of application</th>
<th>Streptomycin (lb/ac)</th>
<th>Dinocap (fl. oz/ac)</th>
<th>Zineb (lb/ac)</th>
<th>Copper (lb/ac)</th>
<th>Propineb (lb/ac)</th>
<th>Water gal/ac</th>
</tr>
</thead>
<tbody>
<tr>
<td>11.4</td>
<td>1</td>
<td>0·21(0·24)†</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>25(280)‡</td>
</tr>
<tr>
<td>4.5</td>
<td>2</td>
<td>0·21(0·24)†</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>30(336)</td>
</tr>
<tr>
<td>19–22.5</td>
<td>3</td>
<td>—</td>
<td>6·0(4·2)‡</td>
<td>1·4(1·54)†</td>
<td>0·9(0·99)‡</td>
<td>1·4(1·54)‡</td>
<td>100(1120)</td>
</tr>
<tr>
<td>1–2.6</td>
<td>4</td>
<td>—</td>
<td>6·0(4·2)</td>
<td>2·1(2·38)</td>
<td>1·8(2·03)</td>
<td>2·1(2·38)</td>
<td>100(1120)</td>
</tr>
<tr>
<td>7.6</td>
<td>5</td>
<td>—</td>
<td>6·0(4·2)</td>
<td>2·8(3·15)</td>
<td>1·8(2·03)</td>
<td>2·8(3·15)</td>
<td>100(1120)</td>
</tr>
<tr>
<td>14–15.6</td>
<td>6</td>
<td>—</td>
<td>8·0(5·6)</td>
<td>2·8(3·15)</td>
<td>2·8(3·15)</td>
<td>2·8(3·15)</td>
<td>100(1120)</td>
</tr>
<tr>
<td>26.6</td>
<td>7</td>
<td>—</td>
<td>10(7·0)</td>
<td>3·5(3·92)</td>
<td>2·7(3·02)</td>
<td>2·7(3·02)</td>
<td>100(1120)</td>
</tr>
<tr>
<td>5.7, 17.7, 26.7, 2.8, 14.8, 23–24.8</td>
<td>8–13</td>
<td>—</td>
<td>10(0·70)</td>
<td>3·5(3·92)</td>
<td>2·7(3·02)</td>
<td>2·8(3·15)</td>
<td>200(2240)</td>
</tr>
</tbody>
</table>

*All quantities are of active ingredient

Figures in brackets: ‡kg/ha, †l./ha

Assessment of disease

Powdery mildew assessments were made on three occasions. On 21 June, 
sub-plots (3 rows × 10 plants) were chosen at random in each plot and the leaves 
(50–80) up to breast-wire height (1·5 m) on each plant examined for infection.
At this time the tips of the climbing bines (shoots) had almost reached the top wire, 5 m above ground.

Infection of leaves and young cones was recorded in the same sub-plots on 25 August. Cones of Northern Brewer were almost full size and were borne compactly on short laterals whereas those of the Golding cultivars were small, often still at the flowering stage and were borne on long, lax lateral shoots. For Northern Brewer, two lateral shoots, one about 2 m above ground and the other within 0.5 m of the top wire, were selected randomly from each plant and each leaf and cone recorded as diseased or not. However, for the Golding cultivars, where lateral shoots were difficult to sample, one was selected from within 1 m of the top wire. An average of 660 leaves and 1,400 cones per plot was examined.

The final assessments were made at harvest on 12 September (Northern Brewer), 21 September (Eastwell Golding) and 26 September (Cobbs). The centre row of each plot was picked by machine and a random sample of 300 cones then examined for the presence of both powdery and downy mildews.

**Determination of yield and alpha-acid content of cones**

Fresh weights of cones from the centre row of each plot were determined immediately after picking. Cones were collected periodically from the machine belt during picking to provide random samples of about 1 kg per plot. Following disease assessment, each sample was dried in a miniature kiln for 17 hr at 55°C and determinations were then made of moisture content and lead conductivity value (alpha-acid content – the principal constituent conferring bitterness to beer). Finally, a sub-sample was further dried in an oven for 1.5 hr at 100°C to allow dry matter to be determined. The yield was calculated from these data and expressed as oven-dry weight +10 per cent moisture (= standardised kiln dry weight) per ha.

**RESULTS**

The intensity of powdery mildew varied considerably over the trial area so, to assist interpretation, the results (Table 2) are presented in plot rather than in treatment sequence. Northern Brewer is inherently more susceptible to powdery mildew than the Golding cultivars and is harvested earlier; records from plots 1 and 2a could not, therefore, be compared with those from the other plots. However, the two Golding cultivars were considered together as they are similar both in susceptibility to powdery mildew and in yield and quality of cones.

Powdery mildew developed slowly but progressively as the crop grew and matured. After four applications of dinocap and the treatment fungicides (21 June) the distribution of leaf disease was fairly uniform throughout the trial although the outer plots (1 and 12) remained relatively healthy. By 25 August (after 11 applications) the disease was difficult to find on leaves of the lateral shoots, only one leaf, in plot 5, being recorded as infected. However, the distribution of cone infection, though generally low in amount, suggested that copper might be affording slightly improved control. This impression was confirmed conclusively by the results of the final assessments. Between the last spray applications and harvest, the disease built up to fairly high levels in some plots, especially in the late-picked Goldings. It was consistently most severe in the zineb plots and least severe in those treated with copper. Propineb permitted an intermediate degree of infection and seemed closer to copper in efficiency than to zineb. Lack of uniform replication within the Goldings precluded the use of data from the propineb plots for statistical analysis. The angular transformations of the mean percentages of cones with powdery mildew at harvest for the
plots treated with copper and zineb were 13-47 and 20-27 respectively. These were significantly different at the 5 per cent level of confidence (L.S.D.=5-88).

### TABLE 2

**Powdery and downy mildew incidence, yield and quality of hops in the trial**

<table>
<thead>
<tr>
<th>Plot*</th>
<th>Cv.†</th>
<th>Treatment</th>
<th>Powdery mildew</th>
<th>Downy mildew</th>
<th>Yield and quality of cones</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>No. hills/30 with infected leaves 21 June</td>
<td>Per cent cones infected 25 Aug</td>
<td>Per cent cones infected At harvest</td>
</tr>
<tr>
<td>1</td>
<td>NB</td>
<td>Propineb</td>
<td>0</td>
<td>0-7</td>
<td>3-0</td>
</tr>
<tr>
<td>2a</td>
<td>NB</td>
<td>Zineb</td>
<td>17</td>
<td>1-9</td>
<td>7-3</td>
</tr>
<tr>
<td>2b</td>
<td></td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>3</td>
<td>EG</td>
<td>Copper</td>
<td>16</td>
<td>0-8</td>
<td>5-3</td>
</tr>
<tr>
<td>4</td>
<td>EG</td>
<td>Zineb</td>
<td>18</td>
<td>1-2</td>
<td>17-0</td>
</tr>
<tr>
<td>5</td>
<td>EG</td>
<td>Copper</td>
<td>14</td>
<td>1-2</td>
<td>5-3</td>
</tr>
<tr>
<td>6</td>
<td>EG</td>
<td>Propineb</td>
<td>16</td>
<td>0-1</td>
<td>7-0</td>
</tr>
<tr>
<td>7</td>
<td>EG</td>
<td>Copper</td>
<td>12</td>
<td>0</td>
<td>5-7</td>
</tr>
<tr>
<td>8</td>
<td>EG</td>
<td>Propineb</td>
<td>19</td>
<td>0-8</td>
<td>—</td>
</tr>
<tr>
<td>9</td>
<td>C</td>
<td>Zineb</td>
<td>9</td>
<td>0-3</td>
<td>13-0</td>
</tr>
<tr>
<td>10</td>
<td>C</td>
<td>Propineb</td>
<td>8</td>
<td>0-3</td>
<td>4-6</td>
</tr>
<tr>
<td>11</td>
<td>C</td>
<td>Zineb</td>
<td>11</td>
<td>0-6</td>
<td>7-0</td>
</tr>
<tr>
<td>12</td>
<td>C</td>
<td>Copper</td>
<td>1</td>
<td>0</td>
<td>2-3</td>
</tr>
</tbody>
</table>

*Plot 2 was partly Northern Brewer and partly Eastwell Golding. The 30-plant sample plot was in the former area but final disease and yield assessments were obtained from both.

†NB=Northern Brewer  EG=Eastwell Golding  C=Cobbs

No final results were obtained from plot 8.

After an outbreak of basal spikes (systemically-infected shoots) in May, light downy mildew infection was evident on leaves and cones throughout the year. In a low-lying region of the garden (plots 2–5), where wetness probably persisted for longer periods, this disease suddenly became serious on the cones in September. There were no differences between fungicides for downy mildew control.

The relationships between levels of powdery and downy mildew infection and cone yield and quality was investigated for the Golding plots (Table 3). The results showed that an increase in the severity of powdery mildew in the cones was not accompanied by a reduction in yield or alpha-acid content. Similar findings were obtained from other trials in 1972 (Royle and Griffin, unpublished) where there was a greater range of powdery mildew incidence and the cones were free of downy mildew. In contrast, downy mildew significantly depressed yield in this trial but there was no relationship with the alpha-acid content.

### TABLE 3

**Correlation coefficients between cone infection and yield and alpha-acid content in trial plots of Golding cvs. (n=10)**

<table>
<thead>
<tr>
<th>Kiln dry wt/ha</th>
<th>Alpha-acid wt/ha (per cent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Per cent cones with:</td>
<td></td>
</tr>
<tr>
<td>Powdery mildew</td>
<td>—0-139</td>
</tr>
<tr>
<td>Downy mildew</td>
<td>—0-811**</td>
</tr>
</tbody>
</table>

(significantly different from 0: *at<5 per cent level, **at<1 per cent level)
DISCUSSION

This trial has provided convincing evidence that, in comparison with zineb, copper has useful side-effects against the development of powdery mildew in hops. Propineb, a newer zinc-based dithiocarbamate, appears to be only slightly inferior to copper in this respect. It is not known how copper exerts this effect. Yarwood (1942) investigated its direct effects on Erysiphe spp. in vitro but obtained inconclusive results. Horsfall and Lukens (1966) adopted the view that the main action is indirect, via the host, and quote evidence that copper increases cuticle thickness (Bärner and Röder, 1964) and sugar content of epidermal cells (Horsfall and Dimond, 1957). It is widely believed by hop growers that copper causes brittleness of leaves and cones which may, as a result unfavourably shatter during machine picking.

Just how serious powdery mildew in the cones of a crop needs to be in order to affect yield and quality is unknown and needs to be investigated. Levels of infection encountered in this and other trials in 1972 were finally quite high yet the disease had no apparent effect on the yield and alpha-acid content. However, most infection was the result of late fungal development on the maturing cones whereas the disease is considered to be most serious when invasion occurs at the flowering stage in July. In this situation, and in the absence of a more efficient powdery mildew fungicide, the downy mildew fungicide in use at the time may be an important factor in the efficiency of control. However, in recent trials (Royle and Griffin, unpublished) where zineb was used for downy mildew control, a new organophosphorus fungicide, pyrazophos, gave a high level of control of powdery mildew.

We wish to thank Mr. P. B. Clarke, Chart Court Farm, Little Chart, near Ashford, Kent, for facilities to conduct the trial, Messrs. Boots Ltd. for Coppesan spray and all those who assisted in recording.

REFERENCES


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