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# PRACTICAL EXPERIENCE WITH THE COMBINATION THIABENDAZOLE/CAPTAFOL AGAINST CEREAL FOOT ROT AND EAR DISEASES

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Summary In extensive field trials between 1975 and 1978, a formulated thiabendazole plus captafol mixture used at a rate of 2.0 kg product/ha proved to be effective against eyespot (Cercosporella herpotrichoides) and Fusarium foot rot (Fusarium spp.) in wheat, barley and rye at growth stage 4 to 6 and against ear mildew (Erysiphe graminis) and glume blotch (Septoria nodorum) in wheat at growth stage 10 to 10.5. Suppression of Fusarium ear blight in wheat was also noted.

Control of stem base diseases gave average yield increases of between 5.3 % (eyespot/spring wheat) and 44 % (Fusarium foot rot/winter rye). Control of ear diseases gave average yield increases of between 8.2 % (ear mildew/spring wheat) and 23 % (glume blotch/spring wheat). Increases in yield were mostly related to increases in 1000 grain weight.

Resumé Dans les vastes essais aux champs effectués durant 1975 - 1978, un mélange de formule thiabendazole + captafol (nom commercial DRAWITEK), employé à une dose de 2.0 kg/ha, s'est montré efficace contre la maladie des feuilles noires (Cercosporella herpotrichoides) et la carie de Fusarium, des pieds (Fusarium spp.), se trouvant dans le blé, l'orge et le seigle pendant la phase de croissance 4 à 6, ainsi que contre le mildiou des épis (Erysiphe graminis) et les pustules des glumes (Septoria nodorum) se trouvant dans le blé pendant la phase de croissance 10 à 10.5. On a également constaté la suppression de la rouille des épis, de Fusarium, dans le blé.

Les augmentations moyennes des rendements calculées sur la base d'essais multiples, varient, dans la lutte contre les maladies des pieds des tiges, de 5.3 % (maladie des feuilles noires/blé de printemps) à 44 % (carie de Fusarium des pieds/seigle d'hiver); de même, dans la lutte contre les maladies des épis, elles varient de 8.2 % (mildiou des épis/blé de printemps) à 23 % (pustules de glumes/blé de printemps). Les augmentations de rendements sont, dans la plupart des cas, dues aux augmentations des poids de 1000 grains.

## INTRODUCTION

In recent years the cultivation of cereals has become much more intensive and farmers now have to pay more attention to disease control. The expansion in the cultivation of cereals, especially of the winter varieties which are particularly at risk from several diseases, has undoubtedly led to increased losses from fungal pathogens although many farmers have disregarded this problem perhaps because they have been unaware of the damage done. Recent evidence has shown, however, that in order to achieve high yields and gain maximum benefit from improved varieties and growing techniques, it is necessary to use chemicals to control foot, leaf and ear diseases especially in those years when climatic conditions favour the pathogens.

Our aim was to develop a broad-spectrum fungicide in order to obtain comprehensive control of a range of common cereal diseases. This was achieved by the development of DRAWITEK which is a formulated mixture of thiabendazole and captafol and thus combines a systemic and a non-systemic active ingredient. Thiabendazole, the systemic compound offers effective control of Cercosporella herpotrichoides, Fusarium species and Erysiphe graminis. Captafol was added to extend the efficacy of thiabendazole and especially to improve control of the Septoria diseases. Evaluation of the thiabendazole + captafol mixture, in field trials from 1975 to 1978, is covered by this report.

## MATERIALS AND METHODS

The thiabendazole + captafol mixture was used as an 80 % wettable powder (20 % thiabendazole + 60 % captafol) at a rate of 2.0 kg product/ha in all trials. A total of 225 trials throughout Germany, from 1975 to 1978, tested the mixture against foot rot diseases in winter wheat, winter barley, winter rye and spring wheat (121 trials) and against ear diseases in winter and spring wheat (104 trials). Randomized block designs, with four replicates, were used and plots were each 25 $m^2$. Sprays were applied using a HOLDER portable sprayer with Teejet nozzles (type 11004) at 3.5 bars pressure delivering 400 l/ha. When spraying, the distance between the plants and the nozzles was 50 cm. The mixture was also tested on large plots, of at least 0.5 ha, where treatments were applied by farmers using their own standard farm sprayers. The standard materials used for comparison in the trials were carbendazim (59.4 % w.p.) at 0.3 kg/ha in foot rot disease trials, triadimefon (25 % w.p.) at 0.5 kg/ha in ear mildew trials and captafol (80 % w.p.) at 2.0 kg/ha in Septoria trials.

In all trials, sprays were timed according to crop growth stages recorded on the Feekes-Large scale (Large, 1954). In foot rot disease trials the fungicides were applied at G.S. 4 to 6. In ear disease trials they were applied at G.S. 10 to 10.5. Foot rots were assessed by counting the proportion of straws affected, at the stem base, by each pathogen. Ear diseases were normally assessed at G.S. 11.1 to 11.2 by grading the severity of infection on the ears. In the small plot trials 17.5 $m^2$ were harvested from each plot using a small plot combine. In the large plot trials at least 0.5 ha was harvested from treated and untreated areas using the farmer's combine. Grain samples were taken from each plot and used to estimate 1000 grain weights. In all trials, yield and grain weight data were corrected to 14 % moisture content. In the results both are expressed as a percentage of the untreated.

## RESULTS

### 1. Control of foot rot diseases

#### 1.1. Eyespot (Cercosporella herpotrichoides)

Thiabendazole + captafol was tested in 49 small plot trials on winter wheat, 18 trials on winter barley, 12 trials on winter rye and 15 trials on spring wheat, in all of which Cercosporella was the main pathogen on the stem base. Although details of the disease assessments are not given here it was generally found that thiabendazole + captafol was most effective where Cercosporella was most severe. Average yields and 1000 grain weights of treated plots, relative to untreated (= 100 %) are summarized in Table 1.

Table 1

Average effects of fungicide treatments, applied at G.S. 4 - 6 for eyespot control, on yield and 1000 grain weight of wheat, barley and rye (1975-78)

| Cereal | Treatment (kg/ha) | Relative yield | Relative 1000 grain weight |
|---|---|---|---|
| Winter wheat | thiabendazole + captafol (2.0) | 111.1 | 106.8 |
| | carbendazim (0.3) | 107.8 | 104.3 |
| Winter barley | thiabendazole + captafol (2.0) | 109.7 | 102.6 |
| | carbendazim (0.3) | 107.6 | 101.5 |
| Winter rye | thiabendazole + captafol (2.0) | 105.6 | 101.8 |
| | carbendazim (0.3) | 106.9 | 101.3 |
| Spring wheat | thiabendazole + captafol (2.0) | 105.3 | 101.1 |

Similar results were achieved in the large plot trials. In 16 trials with winter wheat and 9 trials with winter barley, thiabendazole + captafol increased yields by an average of 12.3 and 8.9 % respectively.

1.2. Fusarium foot rots

Severe infection of the stem base by Fusarium spp. does not occur every year. It is most common in dry years and in arid districts. In 1975 we observed severe Fusarium in two small plot trials with spring wheat (cultivar Kolibri) in southern Germany, and again in 1976 in 1 small plot trial with winter rye (cultivar Kustro) near Mainz. Table 2 summarizes the effects of the fungicides on Fusarium and on yield and 1000 grain weight.

Table 2

Effects of fungicides applied at G.S. 5 - 6, on Fusarium infection, yield and 1000 grain weight of spring wheat (1975) and winter rye (1976)

| Cereal and trial site | Treatment (kg/ha) | Fusarium infection (% straws) | Relative yield | Relative 1000 grain weight |
|---|---|---|---|---|
| Spring wheat Grabenstätt | untreated | 68.4 | 100 | 100 |
| | thiabendazole + captafol (2.0) | 24.5 | 120 | 123 |
| | carbendazim (0.3) | 50.1 | 105 | 111 |
| Spring wheat Kronest | untreated | 58.3 | 100 | 100 |
| | thiabendazole + captafol (2.0) | 15.4 | 126 | 127 |
| | carbendazim (0.3) | 47.3 | 104 | 102 |
| Winter rye Mainz | untreated | 59.6 | 100 | 100 |
| | thiabendazole + captafol (2.0) | 34.1 | 111 | 103 |
| | carbendazim (0.3) | 53.3 | 102 | 102 |

Exceptionally severe Fusarium foot rot was obtained in a winter rye (cultivar Carokurz) trial in 1978, testing the effects of nitrogen fertiliser, done by the Plant Protection Office, Osnabrück on light sandy soil. In this trial, thiabendazole + captafol gave substantial control of the disease, leading to much reduced lodging and very large increases in yield (Table 3).

Table 3

Influence of nitrogen fertiliser and thiabendazole + captafol sprays (at 2.0 kg/ha) on Fusarium infection, lodging, yield and 1000 grain weight of winter rye grown on sandy soil

| Nitrogen[1] | Treatment | Fusarium infect. (% straws) | Lodging (0-9 scale) | Yield dt/ha | rel. | Relative 1000 grain weight |
|---|---|---|---|---|---|---|
| 120 (3x40 CAN) | untreated | 98 | 9 | 40.0 | 100 | 100 |
| | thiabendazole + captafol | 56 | 4 | 57.6 | 144 | 100 |
| 150 (70 CAN + 2x40 CAN) | untreated | 85 | 7 | 40.1 | 100 | 100 |
| | thiabendazole + captafol | 52 | 3 | 56.3 | 140 | 118 |
| 150 (70 CAN + 80 CC) | untreated | 81 | 7 | 45.2 | 100 | 100 |
| | thiabendazole + captafol | 46 | 4 | 57.9 | 128 | 107 |

[1] CAN = calcium ammonium nitrate; CC = calcium cyanamide

## 2. Control of ear diseases

### 2.1. Ear mildew (Erysiphe graminis)

Between 1976 and 1978 there were 28 small plot trials on winter wheat and 12 trials on spring wheat in which infection by Erysiphe graminis was dominant and infection by Septoria nodorum either did not occur or was considered to be unimportant. In Table 4 the average yields and 1000 grain weights of treated plots relative to untreated (= 100 %) are summarized.

Table 4

Average effects of fungicide treatments, applied at G.S. 10 - 10.5 for control of ear mildew, on yield and 1000 grain weight of winter and spring wheat (1976 - 1978)

| Cereal | Treatment (kg/ha) | Relative yield | Relative 1000 grain weight |
|---|---|---|---|
| Winter wheat | thiabendazole + captafol (2.0) | 109.4 | 106.9 |
| | triadimefon (0.5) | 110.1 | 103.2 |
| Spring wheat | thiabendazole + captafol (2.0) | 108.2 | 106.5 |
| | triadimefon (0.5) | 109.7 | 102.6 |

## 2.2. Glume blotch (Septoria nodorum)

Between 1975 and 1978, 32 small plot trials on winter wheat and 14 trials on spring wheat were located in areas where infection by Septoria was expected to occur. The results of these trials, in none of which was ear mildew considered to be important, are summarized in Table 5.

Table 5

Average effects of fungicide treatments, applied at G.S. 10 - 10.5 for control of glume blotch, on yield and 1000 grain weight of winter and spring wheat (1975 - 1978)

| Cereal | Treatment (kg/ha) | Relative yield | Relative 1000 grain weight |
|---|---|---|---|
| Winter wheat | thiabendazole + captafol (2.0) | 115.3 | 112.7 |
| | captafol (2.0) | 112.2 | 113.4 |
| Spring wheat | thiabendazole + captafol (2.0) | 123.0 | 117.8 |
| | captafol (2.0) | 116.5 | 114.0 |

Many large plot trials were done in southern Germany, in areas where severe Septoria can be expected in most years. Disease control in these trials, where thiabendazole + captafol was applied, and the resulting increases in yield, are largely in accord with the results quoted in Table 5. In 10 trials with winter wheat and 8 trials with spring wheat, average increases in yield of 18.5 and 20.7 %, respectively, were obtained.

## 2.3. Fusarium species

As thiabendazole + captafol is so effective against Fusarium diseases of the stem base we have, since 1976, tried to assess its value for controlling Fusarium diseases of the ear. Unfortunately, sufficient disease had not, until this year, developed in any of our trials. However, in 1979 severe Fusarium did develop in 1 small plot trial and in 2 large plot trials in southern Germany. Preliminary assessments indicate that Fusarium on the ear is well controlled by thiabendazole + captafol, although at the time of writing final assessments and yields were not available.

## DISCUSSION

Our results show that sprays of a thiabendazole + captafol mixture applied to wheat, barley and rye at G.S. 4 to 6 can cause large increase in yield and 1000 grain weight. In the limited space available we have not given details of our disease assessments but correlations between the levels of disease control and the subsequent yield increases were not obtained in all trials. Generally we find that the decrease in Cercosporella infection, after spraying, is greatest on those sites where there is most disease. The effect of the spray, both in decreasing infection and in increasing yield, was greater on good soils than on light sandy soils. These results correspond in general to practical experience and to the results of large plot trials carried out by official investigators.

The observed activity of thiabendazole + captafol against Fusarium foot rots is the more remarkable as the fungicides commonly used until now for the control of cereal foot rot diseases have shown no effect against Fusarium species.

The results presented in this report show that Fusarium infections of the stem base, especially in spring wheat and rye, can cause serious yield losses.

Under conditions of intensive cereal cultivation, now so common throughout Europe, many crops can be expected to be at risk from these foot rot pathogens. In recent years, weather suitable for infection has commonly occurred in spring and it seems likely that chemical control of foot rot diseases will often be economically justified, and especially on the better soils.

The formulated mixture of thiabendazole + captafol at 2.0 kg/ha has proved effective against powdery mildew and glume blotch on the ears of winter and spring wheat in both replicated and large plot trials. Although we have not given details of the disease assessments, in most of the trials, yield increases could be correlated with amounts of disease in untreated plots. In those trials where disease was less severe, there was often little evidence of such a correlation. Preliminary results suggest that thiabendazole + captafol will also be valuable in the control of Fusarium ear blights but more information is needed before a final judgement is made.

The economic justification for the chemical control of ear diseases on cereals is often questioned. Unfortunately, it is often not easy to predict when severe infections are likely to develop on ears except perhaps when there has been severe disease on leaves. However, the most important ear diseases, powdery mildew and glume blotch, commonly occur together so that high yields will often depend on having available a product or product combination active against both pathogens. Within only 14 days after flowering, about 50 % of the grain yield of the wheat plant has been fixed, primarily by the flag leaf and ear. Bearing in mind that yield losses of 30 % and more have been caused by ear diseases it is clear that all reasonable means must be used to protect the flag leaf and ear from these pathogens. In 5 years of testing we have shown that a mixture of thiabendazole + captafol has excellent activity against these diseases, and others which attack the stem base, and will be a valuable contribution to our efforts to achieve large and stable yields.

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# BROAD-SPECTRUM DISEASE CONTROL IN WINTER WHEAT WITH A MIXTURE OF CARBENDAZIM AND MANCOZEB

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Summary In over 60 small-plot and grower trials in winter wheat from 1974 to 1979, a commercial formulation of carbendazim plus mancozeb regularly gave good yield increases even in the absence of high disease levels. Yields from applications at GS 7 to 8, which tended to be higher than from those applied during ear emergence, could partly be attributed to control of late eyespot development, but also to a reduction in leaf and ear mildew and leaf Septoria. From the 37 trials harvested a mean yield response of 10% was obtained and in over 86% of trials the yield was positive.

Resumé Au niveau d'une soixantaine d'essais réalisés sur blé d'hiver de 1974 a 1979 une spécialité commerciale associant carbendazin et mancozèbe a procuré régulièrement des augmentations de rendements même en situation de faible pression des parasites. Le fait que les rendements obtenus à partir de traitements réalisés au stade GS 7-8 aient été sensiblement plus élevés que ceux correspondants aux applications effectuées à l'apparition des épis pourrait s'expliquer en partie par une meilleure protection contre un développement tardif due piétin-verse mais aussi par une diminution des attaques d'oïdium sur feuilles et épis et de septoriose sur feuilles. Sur 37 essais récoltés l'augmentation moyenne des rendements a été de 10% et dans plus de 86% des cas la réponse rendement a été positive.

## INTRODUCTION

ADAS disease surveys of wheat from 1970 to 1977 have led to estimates of total annual yield losses, due to disease, of between £5.4 and £17.3 million (King, 1977). Eyespot (Pseudocercosporella herpotrichoides) and the more common foliar diseases of Septoria (S.nodorum, S.tritici), mildew (Erysiphe graminis), yellow rust (Puccinia striiformis) and brown rust (Puccinia recondita) are included in these surveys although eyespot was only included from 1975. Disease occurrence and severity are difficult to predict but it is common to find a mixture of diseases occurring in any one crop; Septoria, mildew and eyespot being the more damaging of these. Yellow rust is rarely as damaging, at least nationally, and is not as easy to predict as Septoria and eyespot. Hence there is a need for a broad-spectrum fungicide which will give economic returns even where single diseases do not reach epidemic proportions. Work prior to 1974 carried out in Europe and the U.K. had suggested that it might be possible to control foliar diseases on winter wheat, in particular Septoria, with benzimidazole fungicides. It had also been shown that if the benzimidazole fungicides were applied with a dithiocarbamate, disease control and yield were superior to that achieved from either product alone.

A trial programme was therefore initiated by Hoechst UK Ltd. with a formulated mixture of carbendazim and mancozeb (trade name Kombat). This paper describes the results of these trials carried out between 1974 and 1979 showing that the mixture gives yield increases even in the absence of high disease levels.

## METHODS AND MATERIALS

The carbendazim plus mancozeb mixture used was a wettable powder formulation containing 12% carbendazim and 64% mancozeb. In all replicated trials this mixture was applied at GS 7 to 8 except in 1974 when treatments were also applied at GS 10.3. The standard application rate for the mixture in 1974 and 1975 was 0.3 + 1.6 kg a.i./ha and this was increased to 0.33 + 1.76 kg a.i./ha from 1976 to 1979. The standard material used in 1974 was a tank mix of benomyl (50% w.p.) and maneb (80% w.p.) applied at 0.28 + 1.8 kg a.i./ha. From 1975 to 1977 the standard was a w.p. containing carbendazim plus maneb at 0.25 + 1.6 kg a.i./ha. In 1976 a 50% w.p. formulation of carbendazim at 0.28 kg a.i./ha was also used as the standard for eyespot control. In 1978 the standards were captafol (50% col. at 1.4 kg a.i./ha) and a tank mix of carbendazim (55% water dispersion) and triadimefon (25% w.p.) at 0.28 + 0.13 kg a.i./ha, respectively. In 1979 a w.p. containing triadimefon + captafol at 0.13 + 1.3 kg a.i./ha was included as a standard.

A total of 55 small-plot replicated trials and 13 grower trials was carried out from 1974 to 1979. These were located in East Anglia, Lincolnshire, Oxfordshire, Shropshire, Herefordshire and Kent. In all small-plot trials, treatments were applied using Van der Weij propane sprayers at a pressure of 1,875 mmHg delivering 300 l/ha through eight 110015 Tee Jets mounted 25 cm apart on a 2 m spray boom. Plots were 2 m x 7.5 m with an unsprayed strip of 0.5 m between plots. Treatments were replicated in four randomised blocks. Crop growth stages were defined according to the Feekes-Large scale (Large, 1954).

Foliar diseases were assessed at GS 11.1 on 25 tillers per plot using ADAS Assessment Keys. In 1975 eyespot was assessed at harvest on 25 tillers per plot by scoring them as uninfected, moderately infected (surface tissue only infected with eyespot) or severely infected (one or more eyespot lesion penetrating deep into the stem tissue). From these values an eyespot score was obtained using the formula (% severe tillers + % moderate/2). In 1976 the method of Scott and Hollins (1974) was used taking 25 tillers per plot. In 1974 yields were obtained using the ADAS sample harvest technique (Baldwin, 1968), but in all subsequent years a Hege small-plot combine was used. Sites with uneven or severe lodging were not harvested. In 1974 there were five grower trials which used farmers' sprayers to apply carbendazim plus mancozeb at 0.33 + 1.76 kg a.i./ha at GS 10.1 to an area of about 0.5 ha.

## RESULTS

Results are summarised in Tables 1 to 8. Table 7 shows results from individual trials in 1978 where significant yield and disease data was obtained. Foliar diseases in all years were generally low and thus in 1977 and 1978 disease data could not be obtained from all sites. In the hot, dry summer of 1976 no foliar diseases were recorded although there were significant amounts of eyespot. In 1974 eyespot was not assessed and in trials from 1977 to 1979 no eyespot was recorded.

Table 1

Disease control and yield - 1974 replicated trials

| Treatment | Growth Stage | Mean % disease control, Leaf 2 Septoria | Mildew | Yellow Rust | Brown Rust | Relative yield (Untreated=100) |
|---|---|---|---|---|---|---|
| Carbendazim + mancozeb | 7-8 | 27 | 27 | 30 | 23 | 112 |
| Carbendazim + mancozeb | 10.3 | 27 | 0 | 9 | 0 | 106 |
| Standard | 7-8 | 33 | 20 | 45 | 44 | 110 |
| % infection on untreated | | 6.6 | 3.8 | 1.4 | 10 | (4.3 t/ha) |
| No. of trials | | 8 | 2 | 3 | 1 | 4 |

Table 2

Disease control and yield - 1974 grower trials

| Treatment | Mean % disease control, Leaf 2 Septoria | Mildew | Yellow Rust | Relative yield (Untreated = 100) |
|---|---|---|---|---|
| Carbendazim + mancozeb | 52 | 75 | 26 | 113 |
| % infection on untreated | 8.2 | 0.8 | 3.1 | (4.7 t/ha) |
| No. of trials | 4 | 2 | 3 | 4 |

Table 3

Disease control and yield - 1975 replicated trials

| Treatment | Growth Stage | Mean % disease control: Septoria Leaf 2 | Mildew Leaf 2 | Yellow Rust Leaf 2 | Brown Rust Leaf 1 | Mean Eyespot Score | Relative yield (Untreated=100) |
|---|---|---|---|---|---|---|---|
| Carbendazim + mancozeb | 7-8 | 43 | 48 | 60 | 39(58)* | 16 | 108 |
| Carbendazim | 5-6 | 0 | 0 | - | - | 12 | - |
| Standard | 7-8 | 18 | 56 | 76 | 15(65)* | 13 | 106 |
| % infection on untreated | | 4 | 2.7 | 5.8 | 5.1(5.7)* | 30 | (3.7 t/ha) |
| No. of trials | | 2 | 1 | 3 | 2(1)* | 7 | 3 |

* results in ( ) for control on Leaf 1 from a single application at GS 10.5

Table 4

Eyespot control and relative yield - 1976 replicated trials

| Treatment | Growth Stage | Mean eyespot score | Relative yield (Untreated=100) |
|---|---|---|---|
| Carbendazim + mancozeb | 7-8 | 26 | 113 |
| Carbendazim | 5-6 | 19 | 111 |
| Standard | 7-8 | 26 | 111 |
| Untreated | | 35 | (4.39 t/ha) |
| No. of trials | | 8 | 5 |

Table 5

Disease control and yield - 1977 replicated trials

| Treatment | Growth Stage | Mean % disease control: Septoria Leaf 2 | Mildew Leaf 1 | Mildew Ears | Relative yield (Untreated=100) |
|---|---|---|---|---|---|
| Carbendazim + mancozeb | 7-8 | 74 | 66 | 59 | 108 |
| Standard | 7-8 | 62 | 0 | 51 | 111 |
| % infection on untreated | | 21 | 50 | 40 | (4.52 t/ha) |
| No. of trials | | 1 | 1 | 3 | 5 |

Table 6

Disease control and yield - 1978 replicated trials

| Treatment | Mean % disease control: Septoria Leaf 3 | Septoria Leaf 2 | Septoria Leaf 1 | Mildew Ears | Relative yield (Untreated=100) |
|---|---|---|---|---|---|
| Carbendazim + mancozeb | 57 | 55 | 60 | 51 | 106 |
| Captafol | 34 | 45 | 60 | 20 | 105 |
| Carbendazim + triadimefon | 42 | 59 | 60 | 62 | 108 |
| % infection on untreated | 15.5 | 12.6 | 5 | 8.9 | (6.18 t/ha) |
| No. of trials | 3 | 6 | 1 | 3 | 10 |

All treatments applied at GS 7-10

Table 7

Disease control and yield from individual replicated trials - 1978

| Treatment | Trial No. | % Septoria control Leaf 3 GS 10.5 | % Septoria control Leaf 2 GS 11.1 | % Mildew control Leaf 2 GS 10.5 | % Mildew control Ears GS 11.1 | Relative yield (Untreated = 100) |
|---|---|---|---|---|---|---|
| Carbendazim | 1 | 55 | - | 48 | - | 107 |
| + mancozeb | 2 | - | 62 | - | 64 | 111* |
| | 3 | - | 59 | - | 66 | 109* |
| | 4 | 59 | 100 | - | - | 97 |
| Carbendazim | 1 | 55 | - | 25 | - | 105 |
| + maneb | 2 | - | 50 | - | 46 | 102 |
| | 3 | - | 31 | - | 72 | 112* |
| | 4 | 33 | 100 | - | - | 103 |
| Captafol | 1 | 52 | - | 25 | - | 104 |
| | 2 | - | 7 | - | 10 | 101 |
| | 3 | - | 37 | - | 23 | 108* |
| | 4 | 0 | 88 | - | - | 104 |
| % infection | 1 | 22.5 | - | 6.9 | - | (5.11 t/ha) |
| on untreated | 2 | - | 28.2 | - | 12.6 | (7.05 t/ha) |
| | 3 | - | 7.9 | - | 7.2 | (6.61 t/ha) |
| | 4 | 15 | 2.8 | - | - | (4.94 t/ha) |

Treatments applied at GS 8-9

* Relative yield significantly different from untreated at P = 0.05

Table 8

Disease control and yield - 1979 replicated trials

| Treatment | Mean % disease control: Mildew Leaf 1 | Mildew Ears | Septoria Leaf 1 | Septoria Ears | Relative yield (Untreated=100) |
|---|---|---|---|---|---|
| Carbendazim + mancozeb | 55 | 51 | 68 | 75 | 109 |
| Triadimefon + captafol | 88 | 80 | 68 | 71 | 112 |
| % infection on untreated | 23 | 23.5 | 20.4 | 44 | (5.9 t/ha) |
| No. of trials | 2 | 1 | 4 | 2 | 6 |

Treatments applied at GS 9-10.3

## DISCUSSION

In 1974 during the early development of the mixture of carbendazim plus mancozeb, improved yield responses from early applications at GS 7 to 8 compared to treatment during ear emergence, were noted. (Table 1). Although eyespot was not assessed in 1974, results from 1975 and 1976 suggest that some of this response may have come from the control of late eyespot. In 1976 the average yield response obtained by applying the mixture at GS 7 to 8 was at least as good as that given by the standard eyespot treatment at GS 5 to 6. This effect on late eyespot was noted in 1974 at the Edinburgh College of Agriculture (Gilmour and Gill, 1978). In these trials, carbendazim plus mancozeb applied at GS 9 gave a reduction in the number of whiteheads suggesting activity against eyespot, and in 1977, when the mixture was applied at the normal time for eyespot control (GS 6), eyespot infection was reduced from 39 to 23% giving a yield response of 0.1 t/ha. Control of eyespot with an application of carbendazim plus mancozeb at GS 9 was shown also at the Norfolk Agricultural Station in 1978 (G.M. Palmer and D.B. Stevens, pers.comm.) and, together with a reduction in ear mildew, resulted in a 7.4% yield increase.

The ability of carbendazim plus mancozeb to control foliar disease development and give good yield responses in the absence of eyespot was demonstrated from 1977 to 1979 (Tables 5, 6 and 8). Thus, in 1977, severe mildew on the ears at three sites was reduced by nearly 60% even when treatments were applied before flag-leaf emergence and 10 to 15 weeks before assessment. Yield responses were between 6 and 13%. Although Septoria infections reached the ear only in 1979, carbendazim plus mancozeb at 0.33 + 1.76 kg a.i./ha has consistently given 55 to 65% control of leaf Septoria. In the two trials in 1979 where Septoria glume blotch developed (Table 8) the mixture was applied just before ear emergence. Good disease control obtained by preventing the spread of disease upwards is thus demonstrated for Septoria as it was for mildew. Control of leaf Septoria together with an increase in grain size was obtained also in 1974 at the Norfolk Agricultural Station, when the above mixture was applied to single observation plots at GS 10.1-10.2. In 1977 these results were confirmed in replicated trials; carbendazim plus mancozeb applied at GS 10.3 giving a significant reduction in Septoria and improvement in ear colour due to the control of sooty moulds, and a significant yield increase. In a separate trial, carbendazim plus mancozeb applied at GS 10.4 gave a significant reduction in mildew especially on the flag leaf and again, a considerable improvement in ear colour (M. Nuttall, pers. comm.). Good control of mildew was also demonstrated in 1976 at the North of Scotland College of Agriculture (Anon., 1978) where two applications at GS 8 and 10.1 gave a significant yield increase of 26%. In the same year at Edinburgh (Gilmour and Gill, 1978) control of mildew from an application of carbendazim plus mancozeb at GS 10 gave a yield response of 0.4 t/ha.

Control of rusts has been variable. The diseases were only recorded in trials in 1974 and 1975. In 1975 carbendazim plus mancozeb applied at GS 7 to 8 gave moderate control of yellow rust on Leaf 2 but less control on the flag leaf. Brown rust was better controlled by an application at GS 10.5. Control of yellow rust was observed by D. Gedye and J.C. Atkins of RHM Research Ltd. (pers. comm.) when carbendazim plus mancozeb applied at GS 10.3 to Joss Cambier, gave 80% disease control on both flag leaf and leaf 2, and resulted in an 11% yield increase. In view of the variable results, it seems that crops treated with carbendazim plus mancozeb at GS 7 to 8 might require treatment with a specific rust fungicide if the disease became serious.

Space does not permit the inclusion of data from all individual Hoechst UK Ltd. trials but Table 7 gives an example from 1978. Although significant yield responses were obtained at sites where better control of ear mildew was recorded, the significance of correlations such as this is in some doubt when taken in the context of the

consistency of yield responses, even at sites where disease was apparently absent. In 1978, significant yield responses were obtained in three out of the four trials which showed no disease development, with a mean response of 8%. Out of the total of 37 trials harvested from 1974 to 1979, 32 gave positive responses to carbendazim plus mancozeb with a mean response of 10%. Cook (1977) also obtained yield responses to fungicide sprays which had little effect on Septoria development and reported reductions in Septoria node infection which may have been another cause of the yield responses reported in this paper. Effects on leaf surface microflora, such as those demonstrated by Dickinson and Wallace (1976) and Mappes and Hampel (1977) may also have contributed towards these yield responses. Carbendazim plus mancozeb is thus an effective material for maintaining the yield potential of winter wheat.

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