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TRIALS IN THE U.K. TO EVALUATE BENOMYL, CARBENDAZIM AND DITHIOCARBAMATE MIXTURES FOR YIELD RESPONSE AND CONTROL OF SEPTORIA, EYESPOT AND MILDEW IN WINTER WHEAT

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Summary Two years of extensive field trials with benomyl and carbendazim plus dithiocarbamate mixtures applied from G.S. 8-10.1 in winter wheat gave consistent yield increases. Foliar disease levels were generally low but treatments gave partial control of wheat mildew (*Erysiphe graminis*) with a slight effect against Septoria (*Leptosphaeria nodorum*). Increases in yield were related to increases in grain size. Early application of benomyl at G.S. 4-6 provided a high degree of control of Eyespot (*Cercosporella herpotrichoides*).

Résumé Deux années d'essais extensif en plein champs des mélanges benomyl et carbendazim plus dithiocarbamates appliqués à partir du stade J.S. 8-10.1 sur blé d'hiver ont mis en évidence chaque année des accroissements de rendements. D'une façon gènèral les infestations foliaires ont été de faible intensité mais les traitements permirent de lutter dans une certaine mesure contre l'oidium du blé (*Erysiphae graminis*) ainsi que marginalement contre la septoriose (*Leptosphaeria nodorum*). Les augmentations de rendements ont été liés aux accroissements de taille du grain. Les applications tôt en saison de bénomyl au stade J.S. 4-6 ont permis d'obtenir un excellent contrôle du Piétin-verse (*Cercosporella herpotrichoides*).

INTRODUCTION

The intensification of cereal production, particularly winter wheat, and the introduction of higher yielding varieties has tended to accentuate other limiting factors such as disease susceptibility. Disease surveys carried out in recent years by the Plant Pathology Laboratory of the Ministry of Agriculture have shown that even in a light disease year, such as 1974, 10% of leaf 2 was affected by foliar diseases. Septoria in particular has been the cause of national yield losses, varying between 1 and 8% during 1970-74.

On the Continent, in France in particular, significant increases in yield have been reported (Lescar, Bouchet and Faivre-Dupaigre 1973) from the application of broad spectrum fungicides to intensively grown, high yielding wheat. Ministry of Agriculture trials in 1972 (personal communication) demonstrated that a mean loss of 26% in yield could occur in winter wheat from disease attack throughout the year but a programme of benomyl sprays could provide effective disease control.

All these factors provided the basis for the intensive development programme which started in 1973.

Our initial aim was to demonstrate yield responses, grain quality effects and disease control in winter wheat after spraying with benomyl + dithiocarbamate mixtures in areas where foliar diseases, particularly Septoria, were prevalent. Timing was based on the need to protect the flag leaf, which contributes 60% of yield in winter wheat.

METHODS AND MATERIALS

1973 Seventeen replicated trials were carried out with plot size varying between 2 x 15 m to 5.5 x 27.4 m depending on whether harvesting was carried out by a mini-combine Hege 125 or a standard farm combine. Design layout was randomised with treatments replicated 4 times. Treatments were applied between Feekes Large G.S. 8-10.1 (37-50 on the Zadok, Chang and Konzac scale).

The small plots were sprayed with a Van der Weij small plot sprayer, boom width 2 metres using Delevan H. 80 nozzles spraying at 1.8 bars. Rate of application was 333 l./ha. The larger plots were sprayed with a 2.7 m Dorman wheelaway sprayer with cone nozzles at similar pressure and volume.

Disease assessments were carried out according to the standard MAFF 1971 scale.

Wheat varieties were chosen as those representing the ones principally recommended by the N.I.A.B. and included M. Ranger, Champlein, Cappelle, W. Desprez, M. Nimrod and M. Widgeon. Trials were generally located in areas or fields where foliar disease infection, particularly Septoria, was considered likely to occur.

The treatments included untreated, benomyl 0.28 kg/ha, maneb or maneb + mancozeb 1.79 kg/ha and benomyl at 0.21, 0.28 and 0.35 kg/ha each with 1.79 kg/ha dithiocarbamate as either maneb, mancozeb or a mixture of maneb and mancozeb. Formulations used were the standard commercial preparations available of 50% benomyl (BENLATE), 80% maneb (MANZATE), 80% mancozeb (DITHANE) and a mixture of equal parts maneb + mancozeb.

1974 Nineteen replicated trials were carried out with a further 14 grower trials undertaken in the same fields as the replicated trials. The aim was to investigate the difference in response between small and large plots under the same conditions. A further 63 selected commercial sites were monitored where growers had sprayed half a field of a particular variety. The wheelings were always included when harvesting the commercial sites.

Trials and commercial monitoring were undertaken in a range of varieties including M. Ranger, W. Desprez, M. Nimrod, M. Fundin, Cappelle, Atou, Bouquet, M. Huntsman and M. Widgeon. Geographical distribution covered Devon and Cornwall, Wiltshire, Gloucester, Somerset, Hampshire, Kent, Sussex, Oxford, Hertfordshire, Bedford, Leicestershire, Cambridge, Essex, Suffolk, Yorkshire, Nottinghamshire and Lincolnshire.

In the replicated trials plot size, spraying equipment and disease assessments were similar to 1973. More stress was laid on grain size and sieve analyses were undertaken.

A separate programme was initiated to follow up the high levels of eyespot control achieved in France, Germany, New Zealand and other countries with an early (tillering) benomyl spray.

Treatments for foliar diseases included benomyl at 0.28 kg/ha, maneb or maneb + mancozeb 1.79 kg/ha, a formulated mixture of carbendazim 0.28 + maneb 1.79 kg/ha under the code number DPX 164 and benomyl 0.28 + maneb 1.79 kg/ha as a tank mix. For eyespot the only treatment was benomyl at 0.28 kg/ha applied at the late tillering stage. DPX 164 was formulated as a wettable powder containing 10% carbendazim and 64% maneb.

RESULTS

1973 yield and disease control figures are given in Table I. 0.28 kg/ha benomyl alone gave a yield increase of 6.7% (0.31 t/ha). The addition of dithiocarbamate at 1.79 kg/ha to 0.28 kg/ha benomyl gave a higher response namely 8.5% (0.39 t/ha). When the dithiocarbamate was added to 0.21 kg/ha benomyl there was an 8.0% (0.37 t/ha) increase over control, and 0.35 benomyl achieved a 9.1% (0.42 t/ha) increase. Results did not indicate any difference in response between maneb, mancozeb or a mixture of maneb and mancozeb. There was a similar level of yield response noted in all the varieties tested.

Table 1

Mean results from the 17 replicated trials carried out in 1973

Treatment	Rate kg a.i./ha	Yields t/ha	*No. of trials P= 0.05	% Increase	Septoria % Leaf 2 G.S.11.1-11.2	Mildew % Leaf 2 G.S.11.1-11.2
Untreated	-	4.61	-	-	25.8	4.1
benomyl	0.28	4.92	3	6.7	13.1	3.5
benomyl + dithiocarbamate	0.21 + 1.79	4.98	2	8.0	17.9	4.3
benomyl + dithiocarbamate	0.28 + 1.79	5.00	4	8.5	18.9	4.2
benomyl + dithiocarbamate	0.35 + 1.79	5.03	3	9.1	18.5	4.5

* No. trials where treatment significantly differed from control

Mildew levels were low and no difference in disease incidence occurred between treatments. Septoria control did not reach 50% in any of the treatments and there was no apparent correlation of yield increase and control. No rusts (Puccinia striiformis and P. recondita) were encountered.

1974 yield results are given in Tables 2, 3 and 4. Yield increases were lower than in the 1973 replicated trials; however increases from the grower trials and commercially monitored applications proved to be greater than those from the small plot trials. Benomyl alone gave a yield increase of 2.6% (0.17 t/ha); the addition of maneb 1.79 kg/ha increased the response to 3.1% (0.20 t/ha). The pre-formulated mixture of carbendazim + maneb at 0.28 + 1.79 kg/ha gave the best yield response with 5.4% (0.35 t/ha) which was superior to the tank mix of comparable rates of benomyl + maneb.

Table 2

Mean results from the 19 replicated trials carried out in 1974

Treatment	Rate kg a.i./ha	Yields t/ha	% Increase	% Septoria Leaf 2 G.S.11.1-11.2	% Mildew Leaf 2 G.S.11.1 - 11.2
Untreated	-	6.46	-	9.5	3.1
benomyl	0.28	6.63	2.6	7.8	1.4
dithiocarbamate	1.79	6.54	1.2	7.1	2.8
benomyl + maneb (tank mix)	0.28+1.79	6.66	3.1	6.9	1.3
carbendazim + maneb	0.28+1.79	6.81	5.4	7.0	1.6

Disease pressure was lower in 1974 with only 9.5% Septoria and 3.1% Mildew on Leaf 2 at G.S. 11.1-11.2. Mildew levels were reduced to around 50% as a result of treatment but Septoria was only slightly reduced by the different treatments.

The grower trials results recorded from commercial applications in the same fields where 14 of the replicated trials were carried out, showed a greater response (6.0% or 0.39 t/ha) than the similar benomyl + dithiocarbamate tank mix application in the small plot trials. A mean yield increase of 8.8% (0.56 t/ha) was recorded from the benomyl + dithiocarbamate 0.28 + 1.79 kg/ha commercial applications. Of the further 63 commercial sites recorded, 55 of the sites gave yield increases of 0.18 t/ha or more and of which at 37 sites yields were increased by 0.4 t/ha or more. Specific disease assessments in the grower trial areas was not undertaken. Disease was low, except for yellow rust on susceptible varieties, in all the commercial treatments but no assessments were carried out.

Table 3

Mean results from 14 grower trials carried out in 1974

Treatment	Rate kg a.i./ha	Yields t/ha	% Increase
Untreated	-	6.50	-
benomyl + dithiocarbamate	0.28 + 1.79	6.89	6.0

Table 4

Mean results from monitoring 63 commercial applications of benomyl + dithiocarbamate in 1974

Treatment	Rate kg a.i./ha	Yields t/ha	% Increase
Untreated	-	6.35	-
benomyl + dithiocarbamate	0.28 + 1.79	6.91	8.8

Yield increases were recorded in most varieties but comparative varietal responses were not measured at any one site. Yield increases were reported for most varieties - M. Ranger (5 sites) 8.7%, M. Nimrod (3 sites) 12.3%, Cappelle (4 sites) 8.2%, Atou (4 sites) 13.0%, Bouquet (6 sites) 6.8% and M. Huntsman (22 sites) 8.6%. Increases were independent of the base yield. Analysis of the commercial results and replicated trials indicated comparable yield responses in all the areas tested from Cornwall through Essex and Oxford to Yorkshire.

Responses on a county basis included Somerset (2 sites) 12.1%, Kent and Sussex (4 sites) 6.0%, Hampshire (4 sites) 4.2%, Essex (10 sites) 9.1%, Suffolk (7 sites) 8.7% and Lincolnshire (7 sites) 9.5%.

Table 5

Mean results from sieve analyses of grain samples from 16 replicated trials in 1974

Treatment	Rate	$\frac{\text{Weight of Grain} > 3.25 \text{ mm in treated}}{\text{Weight of Grain} > 3.25 \text{ mm in untreated}} \times 100$
Untreated	-	100
benomyl	0.28	101.3
dithiocarbamate	1.79	102.3
carbendazim + maneb	0.28 + 1.79	105.2
benomyl + dithiocarbamate	0.28 + 1.79	105.5

As Table 5 shows there was an increase in the proportion of top-size grain i.e. over 3.25 mm following treatment. Treated grain was generally plumper, bolder and brighter. Less dust was reported when harvesting some trial and commercial sites. In 30 of the farmer applied sites a mean of 11.4% increase in grain over 3.25 mm was obtained compared with unsprayed.

No specific straw colour and quality assessments were carried out but trial staff and farmer comment indicated frequent improvements in colour. This was usually due to the control of Cladosporium spp. There was a tendency for yield responses to be slightly higher where cereals had been grown intensively over recent years. 20 grower or commercially applied sites were extracted for earthworms in late summer after harvest and the following March. Formalin extractions found there was no difference in the numbers of earthworms between treated and untreated areas at either time.

Table 6

Mean of 6 grower trials carried out in 1974 on eyespot

Treatment	Rate kg a.i./ha	Timing Feekes Large G.S.	% Tillers Infected	% Control
Untreated	-	-	31.9	0
benomyl	0.28	5-7	10.2	55
benomyl	0.28	8-10.1	25.3	21
benomyl	0.28	5-7 + 8-10.1	9.3	57

Table 6 shows that eyespot levels can be reduced with early treatment (G.S. 5-7) but that later spraying (G.S. 8-10.1) is only likely to lead to around 20% control. Early plus late spraying was only of marginal benefit in terms of strict eyespot control over the early spray alone. Treatment between G.S. 5-6 gave the best control.

DISCUSSION

The 1973 trials programme demonstrated that consistent yield increases could be obtained from benomyl sprays applied just prior to ear emergence. There was greater yield benefit by adding 1.79 kg/ha dithiocarbamate to the benomyl. Although the yield response was lower in replicated trials in 1974, grower trials and yields from commercially applied benomyl + dithiocarbamate at 0.28 + 1.79 kg/ha gave consistent yield increases averaging 6 and 8.8% respectively. Although no comparative varietal responses were investigated most varieties responded favourably to treatment in all the counties where investigations were carried out.

Replicated trials established the value of the preformulated mixture which would be easier to handle and use by the farmer.

Treatment with carbendazim + maneb or benomyl + maneb resulted in a greater proportion of larger grain, i.e. over 3.25 mm, in both the replicated trials and the farmer applied sites. It is probable that the larger grain was the result of more healthy leaves enabling metabolism to take place over a longer period. The brighter grain with less dust reflects the reduction of saprophytic moulds.

Overall disease pressure was low in 1974 and the reduced yields in the replicated trials reflect the lower disease levels, in particular of Septoria which was 9.5% on untreated plots as opposed to 25.8% in 1973. Mildew levels were low in both years.

There was no apparent direct relationship between yield increase and disease control. However, in the replicated trials in 1973 and 1974 a significant correlation (significant at 0.1%) was found between the yield increase on plots treated with benomyl + maneb (1973) and carbendazim + maneb (1974) and the level of Septoria in the untreated plots at the end of July (G.S. 11.2). There was no correlation between yield response and Septoria present at spraying. The degree of effectiveness of treatment is therefore dependent on the subsequent development of disease.

While the value of keeping leaves 1 and 2 green and healthy is important, the effects of subclinical levels of Septoria, eyespot and perhaps other diseases, such as Fusarium, in nodes and stem bases may be critical to the overall performance of plants. In addition, the yield responses reported from treatments applied to the flag leaf may have resulted from partial control of eyespot (Doodson and Saunders, 1969), and from the control of unrecorded fungi.

Trials have shown the good level of control of eyespot following treatment with straight benomyl at the late tillering stage. Late spraying provided only limited control of eyespot so that early treatment between G.S. 5-6 is necessary for optimum control.

In conclusion two seasons of extensive development have shown that regular yield increases can be obtained by spraying winter wheat varieties with benomyl + dithiocarbamate or carbendazim + maneb mixtures just prior to ear emergence. The improvement in grain yield and quality of treated crops has not often been related to apparent control of disease.

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EVALUATION OF THIOPHANATE-METHYL FOR DISEASE CONTROL AND YIELD RESPONSE IN CEREALS

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Summary Replicated and user trials for disease control in cereals have been carried out with thiophanate-methyl at 0.7 kg a.i. per ha in England over the two seasons1974 and 1975.

The cereal diseases most susceptible to treatment were *Rhynchosporium secalis* on barley, *Cercosporella herpotrichoides* on wheat, and *Erysiphe graminis* on barley, wheat and oats. *Septoria* diseases were reduced on wheat, but *Puccinia striiformis* and *P. hordei* on wheat and barley were not controlled.

In 1974 consistent yield increases averaging 0.4 tonne/ha directly related to the number of treatments applied and to mildew control, were obtained on barley, and also at one site on oats. On winter wheat an average yield increase of 0.6 tonne of grain per ha was obtained with the early spray applied with herbicide, but a repeat treatment, although improving disease control, did not give a better yield response. In 1975 yield increases from the early spray on wheat and the late spray on barley were lower.

Résumé En Engleterre des essais répliqués et des essais en plein champ ont été réalisés pendant 1974 et 1975 sur le contrôle des maladies des céréales utilisant l'antifongique methyl-thiophanate.

Les maladies des céréales les plus sensibles a l'antifongique étaient *Rhynchosporium secalis* de l' orge, *Cercosporella herpotrichoides* du blé et *Erysiphe graminis* de l'orge, du blé, et de l'avoine. Septorioses du blé (*Septoria* spp.) étaient diminuées, mais *Puccinia striiformis* et *P. hordei* du blé et de l'orge ne fûrent pas controllées.

En 1974 les augmentations régulieres de la production atteignaient une moyenne de 0.4 tonne/ha sur l'orge, et sur l'avoine dans une location. Ces augmentations se rapportaient directement aux nombres des traitements et au niveau de contrôle des mildious. L'augmentation de la production du blé d'hiver atteignait une moyenne de 0.6 tonne/ha aprés un traitement antifongique avec de l'herbicide y compris, mais un traitement de plus, même qu'il améliorait le contrôle des maladies, n'augmentait pas la production. En 1975 les augmentations des rendements apres l'application précoce sur le blé et l'application tardive sur l'orge étaient plus basses.

INTRODUCTION

The fungicide thiophanate-methyl has been tested widely in horticulture (Cole et al 1971 and 1973), and although its activity on powdery mildew of barley was examined in 1970 (Mercer, 1971) it was not until 1974, with the increasing acceptance of cereal fungicides, that trials were conducted on wheat and barley in the U.K. The work was continued in 1975 to obtain more data on eyespot and Rhynchosporium; a trial was also conducted on oats.

METHODS AND MATERIALS

In both years in the unreplicated user trials (62 are reported) treatments of thiophanate-methyl at 0.7 kg a.i./ha were applied by farmers using their own spraying equipment at spray volumes of 220-330 litres/ha. The first application was made as a tank-mix with the herbicide, if used, applying one tankload onto 1½-2 ha at growth stage 4-5 (Feekes' Scale). About 1 ha was treated some 4 weeks later at growth stage (G.S.) 8-9, overlapping it onto the area sprayed earlier and taking care to follow the same wheel markings. In each field there was always an unsprayed control the same size as the treated strips.

In the 1975 replicated experiments (3 are reported) thiophanate-methyl was applied at the same dose as in the user trials, but in addition to the G.S. 4 (early), G.S. 8-9 (late), and the early plus late treatment, an application was made at G.S. 6 in comparison with benomyl and carbendazim. The small plot pressurised sprayer was used, delivering a water volume rate of 315 litres/ha. Plot size was 10m x 10m and there were three replicates for sprays, six for the controls.

The commercial wettable powder formulation of thiophanate-methyl (50% w/w a.i.), 'Cercobin', was used throughout.

Assessments

The Plant Pathology Laboratory cereal disease keys were used for assessing leaf infections of Septoria spp., mildew, and rusts; 25 leaves were taken at random across each plot. Generally the assessment carried out on the second leaf at G.S. 10.5 to 11.1 was found to be the most valuable and is therefore the basis of the results given. Due to the difficulty experienced in separating the effect of Septoria infection from necrotic areas, which could be due to physiological causes, the two conditions were grouped together. Eyespot was assessed on 100 tillers per plot in the user trials and 40 tillers per plot in the replicated trials, the severity of infection also being recorded (Scott and Hollins 1974).

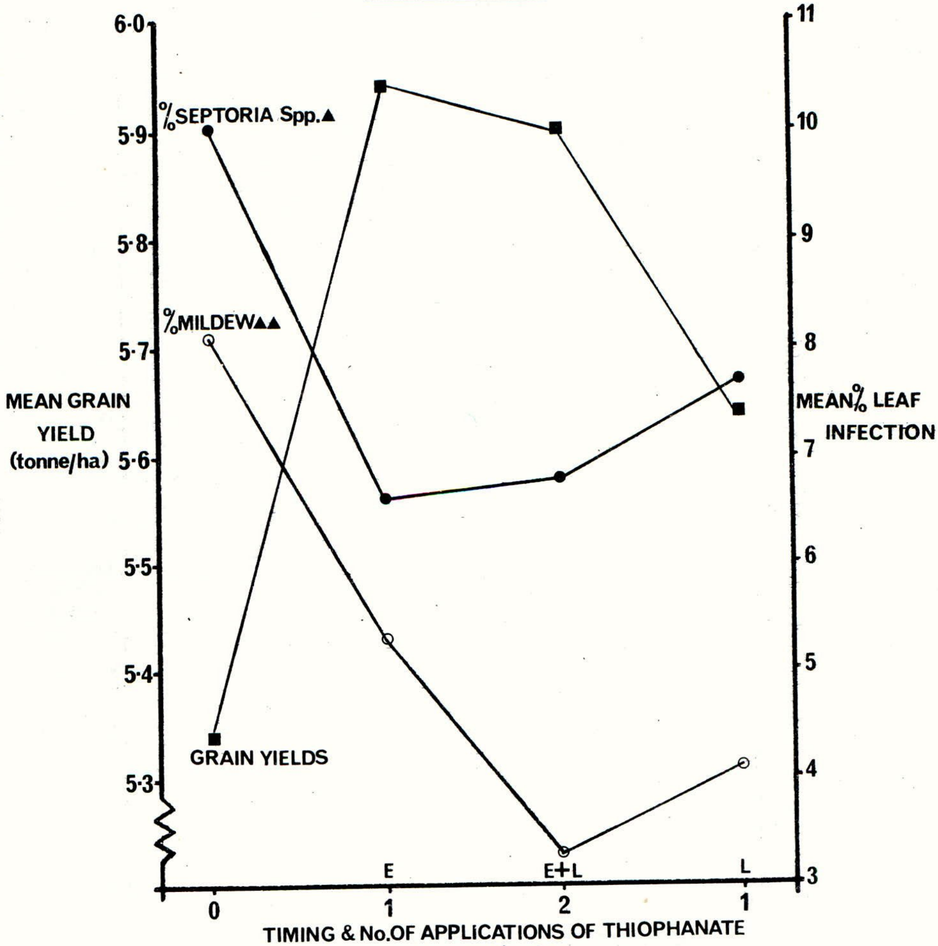
In the user trials grain was harvested and weighed from one combine-harvester width (up to 5m) x 6m strip i.e., 0.02 - 0.04 ha, positioned to avoid crop irregularities and wheelings.

RESULTS

Fig.1

Relationship of yield to disease control on winter wheat - 25 sites

1974 User Trials



E= EARLY APPLICATION (Growth Stage 4–5) L=LATE APPLICATION (G.S 8–9)

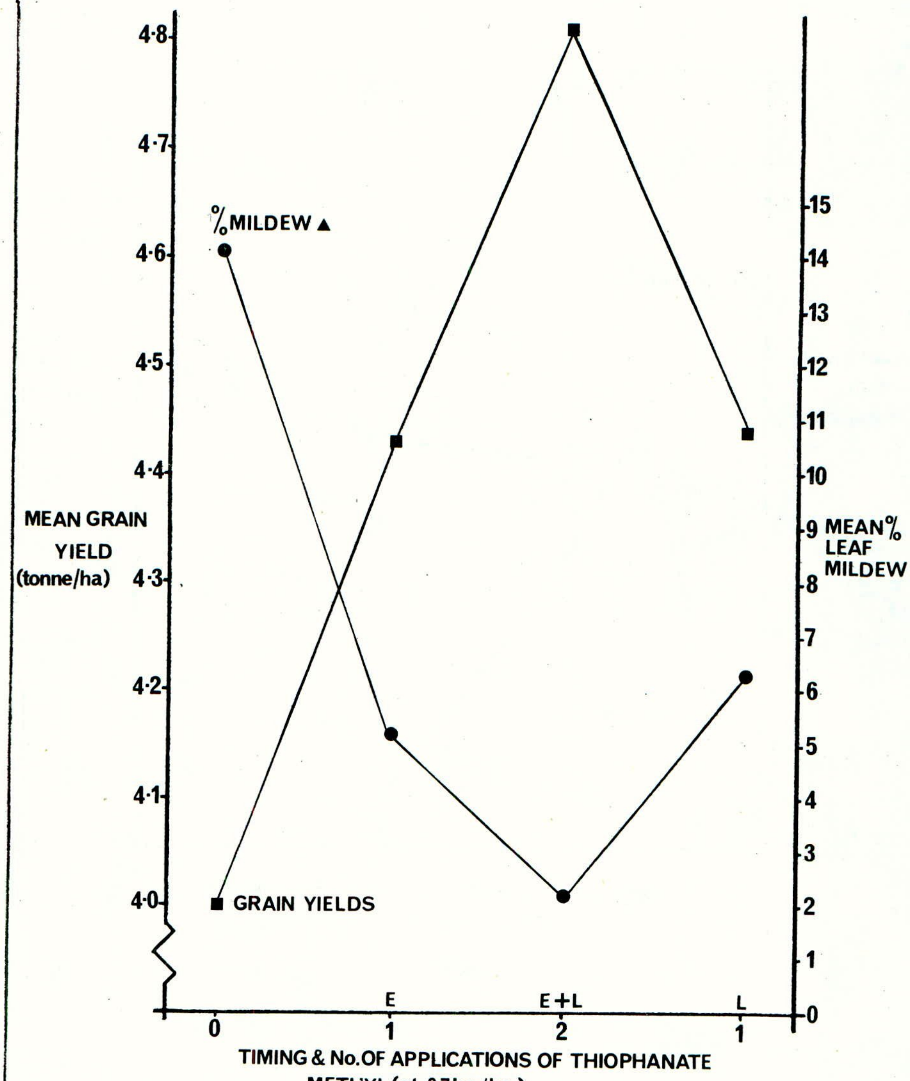
▲=3rd. LEAF ASSESSED MID-JUNE (14–21 DAYS AFTER 2nd.Spray) (22 SITES WITH DISEASE)

▲▲=2nd. LEAF ASSESSED MID-JULY (18 SITES WITH DISEASE)

Fig.2

Relationship of yield to mildew control on spring barley – 8 sites

1974 User Trials



E= EARLY APPLICATION (G.S 4) L=LATE APPLICATION (G.S 8–9)

▲=2nd. or 3rd. LEAF ASSESSED JULY (Growth Stage 11·1)

Table 1

Winter wheat yields - 1974 User Trials

Mean Per Cent Increase over Unsprayed Controls by Region

Thiophanate-methyl 0.7 kg/ha

Region	No.of sites	Early G.S.4-5	Early + Late G.S.4-5 + 8-9	Late G.S.8-9	Control Yield (=100) tonne/ha *
West	11	114	112	103	4.84
East	8	108	110	103	5.98
South East	6	107	107	107	5.46
All areas	25	110	109	105	5.39

* corrected to 85% dry matter.

Table 2

Incidence of Rust Diseases, 1974 User Trials

Mean % leaf infection in early July

Crop	No. of sites Yellow rust	Brown rust	Total	Thiophanate-methyl Early G.S.4-5	Early + Late G.S.4-5 + 8-9	Late G.S.8-9	Unsprayed Control
S.barley	2	3	5	1.0	2.1	1.5	1.7
W.wheat	6	1	7	2.0	2.7	1.5	1.1

Table 3

Effect of thiophanate-methyl on Common Eyespot of Winter Wheat 1975 experiments in Suffolk

Sprayed: early/mid May (G.S. 4), late May/early June (G.S. 6), early/mid June (G.S. 8).

Assessed: July (G.S. 10.5) Rep. X 3 (X 6 for controls)

% tillers infected and disease index (I)*

Treatment	kg a.i./ha	Time of application (G.S.)	Lavenham % infected	Lavenham I	Alpheton % infected	Alpheton I	Parham % infected	Parham I
Thiophanate-methyl	0.7	4	18	8	17	7	28	12
" "	"	4 + 8	4	1.7	13	8	24	8.3
" "	"	8	31	14	35	19	66	39
" "	"	6	28	14	45	20	38	21
" "	"	6 + 8	18	8.3	28	16	47	26
Benomyl	0.28	6	30	16	22	12	56	28
Carbendazim	0.25	6	10	13	24	13	48	25
Unsprayed control			42	26	57	33	84	54
Variety			Bouquet		Maris Ranger		Bouquet	

* Scott and Hollins Key

Table 4

Effect of Thiophanate-methyl on Eyespot of Winter Cereals - 1975 User Trials

% tillers infected at G.S. 11

Site	Wheat or Barley variety	Thiophanate-methyl 0.7 kg/ha Early G.S. 4	Thiophanate-methyl 0.7 kg/ha Early + Late G.S. 4 and 8-9	Comparative Product G.S. 6	Control
Alpheton	Astrix	6	4	-	59
"	Maris Ranger	9	9	-	62
Ash	Maris Huntsman	17	19	20ƒ	26
Boxford	Maris Freeman	13 (23)*	4 (10)*	-	76 (0)*
Canterbury	Bouquet	36	38	48**	64
Cavendish	"	21	10	30ƒ	77
Cockfield	Maris Huntsman	7	7	-	22
Elmsett	" "	9	1	-	82
Pershore	Atou	13	10	30ƒ	40
	Mean % infection ø	13.7	9.6		56.8

* Figures in brackets denote a count for sharp eyespot Corticium solani
ƒ carbendazim 0.25 kg/ha ** benomyl 0.28 kg/ha

Table 5

The effect of double or single applications of thiophanate-methyl on barley leaf blotch (Rhynchosporium secalis)

% leaf infection*

Site	Year/Type of trial	Variety	Thiophanate-methyl 0.7 kg/ha Early G.S. 4	Thiophanate-methyl 0.7 kg/ha Early + Late G.S. 4 and 8-9	Thiophanate-methyl 0.7 kg/ha Late G.S. 8-9	Unsprayed Control
Minchinhampton	1974 User	Mazurka	1.6	0.3	1.2	2.8
Shalford Green	" Rep.	Maris Otter	0.4	-	-	2.5
Moreton	1975 User	Maris Otter	0.1	0	0.6	9.5
Ardleigh	" "	Maris Mink	7.6	3.8	22	29
Fakenham	" "	Maris Otter	5.7	7.1	-	13.0
Helmingham	" "	" "	1.8	-	-	8.7
Nottingham	" "	" "	1.0	1.0	3.0	7.0
Clumber Park	" "	Julia	2.0	2.0	5.0	4.0
Walsingham	" Rep.	Maris Otter	0.3	0.2	0.9	2.5
Melton Constable	" "	Maris Mink	2.0	1.4	6.6	10.0
	Mean ø		1.7	1.3	4.1	7.8

* Leaf 2 assessment at G.S. 11.1 (July), except Shalford Green-leaf 4 assessments (23rd May) at G.S. 6

ø To obtain the means in these tables the percentages were transformed to angles and the averages detransformed.

Table 6

Effect of thiophanate-methyl on powdery mildew and yield of winter oats - 1975 User Trial

Variety: Maris Quest — Site: Ongar
Date of Assessment: 4/6 (G.S. 10.5) — Date of Harvest: 22/8

	Thiophanate-methyl 0.7 kg/ha Early G.S. 4	Early + Late G.S. 4 and 8	Unsprayed Control
% mildew infection on leaf 2 *	2.1	0.9	21
Grain yield tonne/ha (85% D.M.)	3.75	3.92	3.49

* 30 tillers examined per treatment

Table 7

Cereal Yields - 1974 and 1975 User Trials

Mean % Increase over unsprayed controls and no. of sites showing a yield increase

Thioph.-methyl 0.7 kg/ha	Winter wheat 1974			Winter wheat 1975			Spring barley 1974			Spring barley 1975		
Timing	Increase %	No.of sites	Yield Range t/ha	Increase %	No.of sites	Yield Range t/ha	Increase %	No.of sites	Yield Range t/ha	Increase %	No.of sites	Yield Range t/ha
G.S. 4-5	10	20	(-.28 to) (1.95)	5	12	(-0.41) (to 0.88)	11	6	(-0.23)) (to 0.79)	8	6	(-0.67) (to 1.47)
G.S.4-5 G.S.8-9	9	20	(-0.4) (to 1.46)	8	13	(-0.26) (to 1.39)	20	7	(-0.09) (to 1.78)	15	6	(-0.13) (to 1.21)
G.S.8-9	5	18	(-1.52) (to 1.43)	-	-	-	10	7	(-0.01) (to 1.05)	2	5	(-0.43) (to 0.64)
Control Yield* tonne/ha			5.39			4.85			4.00			3.88
Total No. of sites	25			15			8			8		

* corrected to 85% D.M.

DISCUSSION

In the 1974 winter wheat user trials an early thiophanate-methyl (G.S. 4-5) spray gave yield increases in 20 out of 25 sites, with an average gain of 0.5 tonne/ha (Figure 1). However, the additional spray at G.S. 8-9 gave no further increase and the single late treatment gave the poorest response, with the exception of the S.E. Region (Table 1). Septoria species were slightly reduced on wheat, and powdery mildew well controlled on both wheat and barley (Figures 1 and 2). The useful yield response of spring barley was directly related to mildew control and the number of treatments applied (Figure 2).

Thiophanate-methyl has no effect on brown or yellow rust (Table 2), but a useful reduction of eyespot was achieved in both the grower and replicated trials in 1975 (Tables 3 and 4). The best results were obtained at G.S. 4 rather than at G.S. 6, with a repeat dose at G.S.8 being of value. Sharp eyespot was not controlled in one user trial (table 4), which agrees with an early field experiment (Jenkyn & Prew 1972).

Data over two seasons have demonstrated the excellent effect of thiophanate-methyl on Rhynchosporium of barley (Table 5), again the earlier treatment giving the best result. This timing gave a yield increase of 0.25 tonne/ha on oats following mildew control (Table 6).

In the 1975 user trials useful increases in grain yield were again obtained on winter wheat, though these were more modest than the previous season (Table 7): at 80% of the sites (12 out of 15) - the same proportion as in 1974 - yield increases were achieved with thiophanate-methyl with little difference according to region; eyespot was the main problem, Septoria diseases being absent. On spring barley there was a poor yield response to single late spray at G.S. 8-9 in 1975, probably due to the dry conditions, but the single early (G.S. 4) and double (early plus late) applications gave relative increases approaching those of 1974; mildew was prevalent, and Rhynchosporium was common on winter barley, particularly in E. England.

During the course of the user trials a wide range of phenoxyalkanoic and hydroxybenzonitrile-based herbicides, and also chlormequat, were added to thiophanate-methyl in the spray tank with no incompatibility problems. Such combined treatments were found to be very convenient to the farmer, saving the cost of one application.

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EVALUATION OF BROAD SPECTRUM SYSTEMIC FUNGICIDES FOR DISEASE AND YIELD RESPONSES FROM SPRING CEREALS

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Summary Field experiments were conducted on spring-sown wheat and barley crops on light and on heavy soils to evaluate disease and yield responses to systemic fungicides. The best responses were obtained from methyl benzimidazole carbamate (MBC) generating fungicides applied as foliar sprays at G.S. 6 or 7. Such fungicides applied as seed dressings contributed less to yield: as also did seed dressings and sprays of mildew fungicides which did not control eyespot. Yield response was related to eyespot control with some probable benefit from a measure of control of foliar pathogens. Experiments indicated that fungicidal control of eyespot improved grain yields largely through enhanced longevity of functional green leaf which resulted in better filled grain. This was most noticeable in those tests in which Cercosporella herpotrichoides was artificially introduced into the crop.

Résumé Des expériences en plein champ sur le blé et l'orge de printemps ont été fait sur des sols légers et des sols lourds pour estimer les effets des fongicides sistémiques sur les maladies et sur les rendements. Les meilleures résponses ont été obtenu avec des fongicides qui génèrent le méthyle benzimadazole carbamate appliquées en pulvérisation au stade 6 ou 7 de croissance. Cettes fongicides appliquees comme traitment des semences ont contribué à un moindre degré pour augmenter le rendement. Aussi les traitements des semences et les pulvérisations avec les fongicides usées contre l'oidium (qui ne combattent pas la piétin-verse) ont donné des resultats semblables. Les résponses des rendements sont le resultat de l'effet contre la piétin-verse mais il y a probablement quelque avantage contre les maladies des feuilles. Des expériences ont demontré que la lutte contre la piétin-verse améliore le rendement par augmenter la longévite de la surface de photosynthèse que donnerait les plus grosses graines. Ca fut observé surtout en les essais où on a fait entrer artificiellement la Cercosporella herpotrichoides dans les plantules.

INTRODUCTION

The economic advantage derived from widespread use of mildew fungicides on barley in Britain has been borne out by the finding that Erysiphe graminis was the major disease of barley in England and Wales in 5 out of 6 years (King 1973). There is also evidence that benomyl does not give the pronounced reduction of powdery mildew achieved by tridemorph, but the effect of benomyl appeared to last longer (Mundy and Owers, 1974). Studies in Ontario showed that whereas ethirimol and benomyl controlled E. graminis in barley, and increased yield, benomyl did not give control for a sufficient period as a seed dressing, but appeared promising as a foliar spray (Edgington, Reinbergs and Shepherd, 1972). Studies at Rothamsted have shown that benomyl and thiophanate-methyl applied as seed dressings plus two foliar sprays reduced powdery mildew in spring barley and spring wheat, but not as effectively as ethirimol. Benomyl and thiophanate-methyl reduced eyespot (Cercosporella herpotrichoides) in winter wheat but did not have a very pronounced influence on yield of any of the three cereals (Jenkyn and Prew, 1973). Work in Germany showed that spraying with carbendazim controlled eyespot best when applied between the end of tillering and the first nodal stage and that mildew and glume blotch (Septoria nodorum) were best controlled by applications shortly before and after earing (Hampel and Locher, 1973). Other studies on winter wheat have shown that a single application of MBC generating fungicide at the end of a 40 day period with high infection probability gave efficient control of eyespot (Fehrmann and Schrodter, 1973).

The studies carried out in 1972, '73 and '74 described here were directed at the exploitation of systemic fungicides for the alleviation of losses from disease under Irish conditions; where virtually all cereals are spring sown, where barley mildew is not a serious problem and where eyespot constitutes a major hazard to intensive grain production.

METHOD AND MATERIALS

Eight spring wheat and spring barley field trials were laid down on heavy soil at Trim, and at Grange, Co. Meath and on light more friable soil at Oak Park, Carlow. Except where otherwise stated plots were 0.013 hectare in area, the experimental layout was a randomized block design and replication was sixfold. The experimental crop on all sites was immediately preceded by at least one, and in some cases up to four cereal crops. Crops were sown from mid to late March, receiving 35 units of N in drilled granulated compound fertiliser and were treated with an appropriate herbicide for weed control. Where seed dressings were included in an experiment, seeding rate was adjusted appropriately. The following fungicide formulations were tested in one or more trials: benomyl 50% w.p., thiophamate methyl 50% w.p., carbendazim 60% w.p., carbendazim 50% w.p., carbendazim + maneb 6% MBC + 64% maneb, w.p., chloraniformethan 25% e.c., ethirimol 80% w.p. tridemorph 75% e.c. triforine 25% e.c. and pyrazophos 33% e.c. Fungicidal sprays were applied at growth stages 6 or 7, except when otherwise stated, with a propane gas sprayer in 330 litre water/ha using 1.6 mm nozzles at 3 kg/cm^2. Grain yields were recorded at harvesting, and were subsequently corrected to 20% moisture.

Crops were observed throughout the growing season for differential effects of chemical treatment. Plots were sampled between growth stages 10.5.4. and 11.2 and disease assessments were carried out. Diseases assessed were those most prevalent in the crop. Take-all, eyespot and Fusarium were assessed as well as foliar diseases. The amount of necrotic leaf was also measured. Leaf diseases and necrotic leaf area were calculated as the percentage leaf area affected by the particular condition. Take-all was assessed on the basis of a disease index (Cunningham 1967). Eyespot infection was similarly calculated. Straws with disease were categorized as severely (lesions extending more than half way round culm) or slightly infected. Values of 2 and 1 were given to straws in the two categories respectively and the percentage infection was calculated as that of the maximum possible rating. Crop lodging was measured by assessing the lodged area in each plot.

When the total or part of the experimental area were artifically infested with the eyespot fungus to supplement natural inoculum, the inoculum was prepared by culturing the fungus on autoclaved sugar beet seed clusters in the laboratory for about seven weeks. The colonised beet seed clusters were spread uniformly over the area to be infested at growth stage 2. Disease and yield measurement were carried out as before.

RESULTS

Disease and yield measurements, on a spring wheat (cultivar Quern) experiment laid down at Trim, Co. Meath in 1972, are presented in Figure 1.

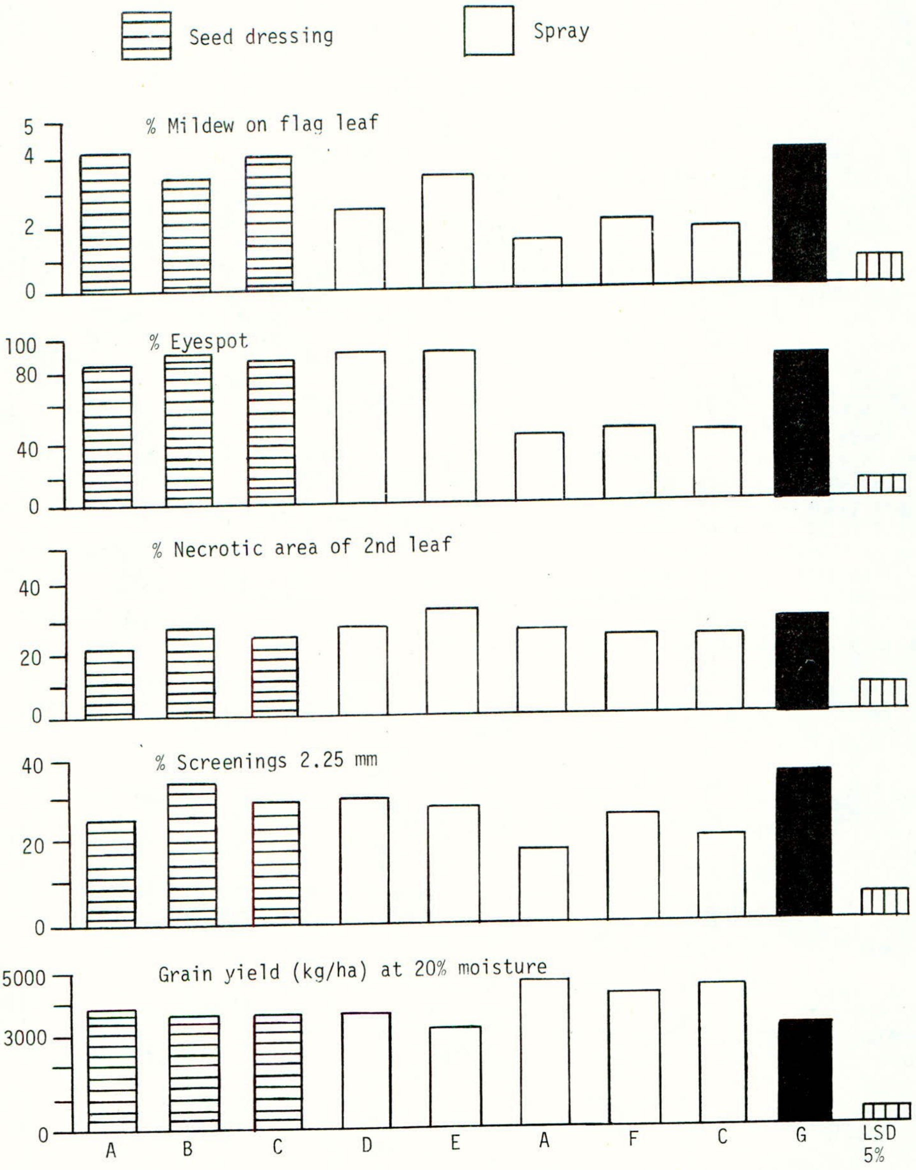
The results (Figure 1) show that the three broad spectrum fungicides benomyl, carbendazim and thiophanate methyl applied as a foliar spray were consistently effective in reducing mildew and eyespot levels, necrotic leaf area and percentage screenings well below those of the control. Grain yields were significantly increased (P=0.001) by these three spray treatments, the mean of these giving a yield increase of 1114 kg/ha (9 cwt/acre approximately). The 1000 corn weight measurements which are not presented showed a highly significant enhancement of grain size from these sprays. Seed dressings, benomyl, carbendazim and ethirimol at time of assessment had little influence on mildew, none on eyespot, slightly reduced leaf necrosis and gave yields which were intermediate between those of the three broad spectrum sprays and the control. Of the seed dressings benomyl increased yield and reduced screenings significantly (P=0.05). While the mildew level was about the same as that in the control at G.S. 10.5.4 this treatment reduced mildew in the pre ear-emergence stages of growth. Tridemorph spray gave a slight reduction in mildew and increase in yield but triforine did not control mildew or eyespot and did not enhance yield. There was about 20 percent lodged crop area in the control plots but less than 5 percent in the broad spectrum spray and benomyl seed dressing treatments. While pycnidia of *Septoria nodorum* were present in some of the necrotic leaf area measured, this pathogen was not considered the main or the only cause of necrosis recorded in the trial.

A similar fungicide experiment was carried out on spring barley (cultivar Emma) on a medium loam soil at Oak Park in 1972. The treatments included MBC generating as well as mildew fungicidal sprays and seed dressings. The results (Table 1) indicate lower levels of disease than in the spring wheat trial previously described. Eyespot was relatively sparse, and there were only occasional mildew pustules and scald (*Rhynchosporium secalis*) lesions. Benomyl, thiophanate-methyl and carbendazim sprays significantly reduced the incidence of eyespot. These treatments also reduced necrosis of the flag leaf and in turn gave significantly higher grain yields, with lower screenings, except that the effect of benomyl on screenings and carbendazim on yield were just short of significance. The mean increase in grain yield from these three treatments was approximately 10 percent, which was achieved in the absence of any lodging.

An experiment was laid down in 1974 on a heavy soil at Grange, Co. Meath, using different rates of carbendazim on Quern wheat. Treatments and results are presented in Table 2. The only measurements in this experiment for which the F value was significant were eyespot, lodged area and grain yield. All rates of fungicide application had a highly significant effect on these three measurements. However, while the difference between 1.12 and 0.56 kg/ha was just significant (P=0.05) for percent eyespot it was not so for percent lodged area or grain yield.

A further experiment was laid down on the spring wheat cultivar Sirius in 1974 with the objective of evaluating the contribution to disease control and yield of a single early spray, a single late spray and an early plus late application (Table 3). Take-all and *Septoria* measurements were not significantly affected by fungicides in this experiment but eyespot level was, and even the late application gave a significant reduction (P=0.05) from that of the control. The early plus late fungicide application was the only treatment to significantly increase hectolitre weight and reduce screenings, whereas the early application of carbendazim and the double application increased (P=0.001) the 1000 corn weight.

Fig. 1: Effect of systemic fungicides on disease level and yield of spring wheat.



Fungicide and rate given as product

Seed Dressing treatments:

A Benomyl 1.12 kg/ha
B Ethirimol 1.0 kg/ha
C Carbendazim 0.56 kg/ha

Spray treatments:

A Benomyl 1.12 kg/ha
C Carbendazim 1.12 kg/ha
D Tridemorph 0.7 l/ha
E Triforine 1.05 l/ha
F Thiophanate 2.24 kg/ha

G Control

Table 1

Influence of systemic fungicide treatment[1] on disease and yield measurements of spring barley

Fungicide and Rate (as formulation)	% Eyespot[2]	% Necrotic leaf[2] (Flag Leaf)	% Screenings < 2.3 mm	Yield kg/ha
Ethirimol Seed Dressing 1 kg/ha	32.0	96.6	7.14	5483
Benomyl Seed Dressing 1.12 kg/ha	40.2	96.4	9.72	5573
Benomyl Spray 1.12 kg/ha	21.9	83.4	7.56	6066
Carbendazim3 spray 1.12 kg/ha	10.0	87.1	5.50	5507
Thiophanate methyl Spray 2.24 kg/ha	14.0	80.2	5.68	5718
Tridemorph Spray 0.7 litre/ha	39.7	97.1	9.88	5530
Ethirimol Spray 2.1 litre/ha	45.3	98.1	10.81	5436
Triforine Spray 1.05 litre/ha	44.3	98.9	8.24	5392
Chloraniformethan Spray 0.7 kg/ha	41.0	99.8	8.17	5247
Pyrazophos Spray 0.7 litre/ha	48.7	99.5	7.05	5296
Control	44.3	97.0	9.73	5256
S.E.	4.49	2.77	1.22	111.7

[1]Sprays applied G.S.7
[2]Sampled 1st August
[3]50% w.p.

Table 2

Effect of rate of carbendazim[1] applied as a spray on disease levels and yield measurements of spring wheat

Rate (as formulation)	1.12 kg/ha	0.84 kg/ha	0.56 kg/ha	Control	S.E.
% Take-all	49.6	48.1	44.5	52.4	3.16
% Eyespot	6.3	9.8	15.5	61.2	2.47
% Lodged (at harvest)	6.8	8.3	9.5	23.8	2.13
1000 corn wt. g	47.2	46.3	46.7	47.2	0.82
% Screenings < 2.25 mm	3.33	3.25	3.95	4.03	0.31
Kg/hl wt.	64.2	64.4	63.7	63.6	0.26
Yield kg/ha	4131	4058	4010	3273	153.1

[1] 60% w.p.

While grain yields from the early and double applications were substantially increased these increases were not significant.

Artificial Infestation Experiments

A programme of field experiments was carried out in which eyespot levels were supplemented through the artificial introduction of inoculum of *C. herpotrichoides*. One such barley experiment (cultivar Emma), in which the entire experimental area was intensely infested with colonised beet seed clusters, was laid down in 1972. This experiment was located on the site of a barley crop in 1971. The effects of benomyl spray treatment (applied G.S.7) on disease and yield responses are presented in Table 4.

The benomyl spray significantly affected all measurements made except necrotic area of 2nd leaf. The most pronounced influence of the fungicide was in the

Table 3

Disease and yield responses of spring wheat to early and late fungicide applications

Growth stage (G.S.) of application of fungicide

	Carbendazim G.S.6	Carbendazim + Maneb G.S.10.3	Carbendazim G.S. 10.3	Carbendazim G.S.6 Carbendazim + Maneb G.S.10.3	Control	S.E.
% Take-all	58.3	56.9	53.6	52.3	54.4	3.98
% Eyespot	24.6	79.4	75.3	16.6	88.0	2.86
% Septoria (Flag Leaf)	3.2	6.5	4.9	4.5	6.2	1.19
Kg/hl wt.	63.3	63.8	63.4	64.6	62.4	0.39
% Screenings < 2.25 mm	3.4	3.1	3.4	1.4	3.6	0.26
1000 corn weight (g)	49.2	46.8	47.6	50.5	45.2	0.68
Yield kg/ha	5284	4982	5123	5344	4803	259

Carbendazim (50% w.p.) applied at 0.84 kg/ha
Carbendazim + Maneb (6% MBC + 64% Maneb) applied at 2.8 kg/ha

Table 4

Disease and yield measurements of barley very severely infected by *Cercosporella herpotrichoides* untreated and treated with benomyl

Disease Index	Treatment: Benomyl Spray (rate as formulation) (1.12 kg/ha G.S.7)	Control	S.E.
% Eyespot (Disease Index	31.5	97.5	3.25
% Eyespot (Severe)	13.5	95.0	5.84
% Plot area lodged	26.8	90.5	3.88
% Necrosed area (2nd leaf)*	82.9	98.8	5.23
1000 corn weight (g)	33.5	31.3	0.42
% Screenings (< 2.3 mm)	6.4	17.4	0.89
Grain yield kg/ha	4910	3609	191

* on 31st July

reduction of severe eyspot, lodged area and screenings. Lodging was a major factor in this experiment and most of the loss can be attributed to eyespot infection since there was scarcely any powdery mildew and only slight *Rhynchosporium* scald present.

In 1973 two similar experiments were carried out on Emma barley and Quern wheat on very light loam soils again artificially infested with the eyespot fungus The preceding crop on this site in 1972 was sugar beet and it was anticipated that in this situation eyespot might be the only disease present at an appreciable level. The results are presented in Table 5. The crops were light in the 1973 trials and eyespot infection did not cause lodging as in 1972. Fungicidal treatment significantly reduced eyespot and leaf necrosis and increased grain yield

Table 5

Disease and yield responses of spring wheat and barley crops to a benomyl spray following artificial infestation with *Cercosporella herpotrichoides*

	Barley			Wheat		
	"*Benomyl 0.84 kg/ha G.S.7	Control	S.E.	"*Benomyl 0.84 kg/ha G.S.6	Control	S.E.
% Eyespot (Disease Index)	26.0	73.0	4.18	33.0	81.5	1.95
% Mildew (3rd leaf)	0.8	1.4	0.29			
% Necrosis (3rd leaf)	71.0	84.0	2.80			
% Ear Septoria				6.6	8.5	0.72
1000 corn weight (g)	36.4	36.3	0.49	40.0	37.3	0.23
% Screenings*	4.68	5.43	0.52	4.90	6.68	0.38
Grain Yield (kg/ha)	5008	4593	63.3	3164	2947	44.1

* Barley<2.3 mm Wheat<2.25 mm "* rates given as formulation

Table 6

Influence of artificially introduced *Cercosporella herpotrichoides* and a benomyl spray (at G.S.6) on spring wheat

	Artificially infested		Non infested		
	"*Sprayed with benomyl 0.84 kg/ha	Unsprayed	"*Sprayed with benomyl 0.84 kg/ha	Unsprayed	S.E.
% Eyespot	10.0	75.9	5.7	24.4	2.90
Grain Yield	3712	3466	3775	3717	92.2

"*rate given as formulation

(P=0.05) in barley (Table 5). In the case of wheat the influence of the benomyl spray on grain yield, 1000 corn weight and screenings was significant (P=0.05) as well as that on eyespot level (P=0.001). Other measurements carried out in this experiment, but not included in the table, which did not give a significant response to spray treatment were grain nitrogen, kg/hl weight and % take-all.

An attempt was made in 1974 to evaluate the contribution to grain yield by the control of introduced eyespot as against control of indigenous eyespot and other diseases. In a fivefold replicated experiment with spring wheat (cultivar Kolibri) plots were artificially infested, or not, with the eyespot fungus followed by spraying, or not spraying, with benomyl. This very light gravelly site was cropped with spring wheat in 1973. Results are presented in Table 6.

Treatment with benomyl reduced the eyespot level of the artificially infested treatment below that of the unsprayed non-infested and almost down to that of the sprayed non-infested (Table 6). The influence of the fungicide with artificial infestation was to increase grain yield by about 250 kg/ha whereas, without artificial infestation the yield increase was only about 60 kg/ha; the LSD (P=0.05) was 278 kg/ha. The yield difference between the artificially infested unsprayed and the non-infested sprayed treatments was 309 kg/ha. There was no differential influence of treatment on take-all or *Fusarium* (prevalent in these experiments) which were also assessed.

DISCUSSION

There is little doubt that under Irish conditions MBC generating fungicides have a contribution to make to spring cereal cropping following cereals except on very light soils. Large yield responses can be expected when crops severely infected with eyespot are treated. It is more difficult to explain substantial yield increases obtained when eyespot is not very prevalent and where only endemic levels of foliar diseases are apparent (Table 1). There is evidence that these fungicides reduce the level of scald caused by *Rhynchosporium secalis* (Cunningham, unpublished data). Another feature observed by the authors from these and other studies was that very good yield responses to fungicide treatment were obtained only from vigorously growing crops; when some factor other than the pathogens controlled by these chemicals, adversely affected growth, yield responses were disappointing. An early spray application directed primarily towards eyespot control is probably underrated in its retarding effects on mildew, *Septoria* and scald. A fungicide applied at G.S.6 may enhance yield potential by arresting these and also possibly miscellaneous pathogens present at very low levels that cause premature death of foliage particularly at the base of the plant before ear emergence.

The data presented (Table 3) shows that yield response from an MBC generating spray at ear emergence is less than that from sprays at growth stage 6. The evidence also suggests that a spray directed primarily towards eyespot control derives some of the yield benefit attained from a later application. However, the main criterion for justification of a late spray with spring cereals would appear to be a late epidemic of foliar disease such as that sometimes caused by *S. nodorum* and which, while influenced by season, may be largely conditioned by local environmental factors.

It is possible to calculate yield loss caused by eyespot using the method of artificial infestation. An infestation x spray factorial experiment on an eyespot-free site would quantify separately the recovered yield from eyespot control as well as that from control of other diseases indigenous to the site. The yield attributable to disease control other than that of eyespot may vary greatly with site. It was virtually nil in the experiment presented in Table 6, whereas it would appear substantial in that presented in Figure 1, as indicated by disease and yield responses from fungicides that did and did not control eyespot. However, the effects of lodging and straggling complicates the losses (direct and indirect) from different levels of eyespot and also there may be an interaction between eyespot infection level and prevalence of foliar diseases.

In addition to the experiments described numerous others were also carried out over the past five years on sites that had carried at least one preceding cereal crop as well as after grass and following root crops. The most consistent and important differences between the influence of an MBC generating spray fungicide on crops following a cereal as against those following a non-cereal were differentials for eyespot level, amount of green leaf and grain yield. Whereas necrosis from mildew and *Septoria* infection will influence the longevity of functional green leaf, eyespot control was considered the major factor in explaining the reduced leaf necrosis following spray applications as well as increased yield. This was indicated particularly by the results of artificial infestation of barley plots with *C. herpotrichoides*.

The use of broad spectrum fungicides on spring cereals following a preceding cereal crop may not always be a profitable practice under Irish conditions. The finding that eyespot infections can be controlled 40 days later (Obst et al, 1973) can be of particular value in devising a plant protection warning system in the context of spring cereals. Such a service would lend itself to a particularly effective system for spray recommendations using climatic and other criteria as influenced by season and region.

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THE USE OF BENODANIL AND TRIDEMORPH PLUS POLYRAM* IN THE U.K. FOR THE CONTROL OF PUCCINIA STRIIFORMIS IN SPRING BARLEY

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Summary During 1974 and 1975, benodanil, tridemorph + Polyram and benodanil + tridemorph were evaluated for control of yellow rust (*Puccinia striiformis*) in spring barley.

Replicated trials were carried out to obtain information on product efficacy and timing of application.

Good control of the disease was observed with all treatments. Although applications containing tridemorph appeared to have better eradicant properties than benodanil alone, the latter tended to be more persistent.

Yield increases were obtained with all treatments. Differences between treatments were marginal, except in trials where powdery mildew (*Erysiphe graminis*) also occurred. In these trials, treatments containing tridemorph gave a greater yield increase than benodanil alone.

It would appear that for most effective yellow rust control, application should be made at an early stage of disease development. Under conditions of early and prolonged infection, a subsequent application may be necessary.

Résumé Pendant 1974 et 1975, on a évalué le benodanil, le tridemorph + Polyram et le benodanil + tridemorph pour le contrôle de la galle. (*Puccinia striiformis*) chez l'orge printanière.

On a effectué des épreuves repliées pour s'informer sur l'efficacité de production et de la règlementation des applications.

On a remarqué un bon contrôle de la maladie avec tous les traitements. Quoique les applications qui contenaient le tridemorph aient paru avoir de meilleures qualités d'éradication que le benodanil seul, celui-ci parait être plus persistant.

Les accroissements de rendement se sont réalisés avec tous les traitements, et les différences entre les traitements étaient peu considérables, sauf aux épreuves où le oidium blanc (*Erysiphe graminis*) est survenu aussi. A ces épreuves, les traitements qui contenaient le tridemorph ont amené un plus grand rendement que le benodanil seul.

Il parait que, pour le contrôle le plus efficace de la galle, il faut faire des applications à un premier degré du developpement de la maladie. Aux conditions d'infection précoce et prolongée, il se peut qu'une application subsequente soit nécessaire.

INTRODUCTION

The activity of benodanil against yellow rust (Puccinia striiformis) on wheat and winter barley was reported by Frost et al (1973), and that of tridemorph + Polyram by Frost and Brown (1973). It has been shown that benodanil is more persistent than tridemorph, but the latter has a better eradicant effect (Frost, 1975).

Trials were carried out during 1974 and 1975 to determine the optimum timing of application for the control of yellow rust in spring barley, and to determine the most effective treatment.

METHOD AND MATERIALS

All trials were of a randomised block design with four replicates of each treatment, and plots measured 4 x 12.5 metres. Treatments were applied with a Van der Weij knapsack sprayer fitted with cone nozzles. Spray pressure was maintained at 2.5 kg/cm^2 and spray volume at 250 l./ha water.

Disease assessments were made using the appropriate key from the Guide for the Assessment of Cereal Diseases, devised by the Plant Pathology Laboratory at Harpenden. Results are expressed as the mean percentage diseased area on the flag leaf, second leaf and third leaf.

Green tissue assessments indicate the percentage area of green tissue remaining, and the results are given as the mean of the flag leaf and second leaf.

Cereal growth stages are expressed using Feekes Large Scale (Large, 1954).

Yield was assessed using a Claas Compact 25 or a Hege 125 combine harvester, harvesting an area of $23m^2$ and $14m^2$ respectively per plot.

Formulations:

Benodanil - 50% a.i. wettable powder

Tridemorph - 75% a.i. w/v emulsifiable concentrate

*Polyram - 80% a.i. wettable powder

Citowett - a non-ionic wetting agent

Polyram is the trade name for zineb-ethylene thiuram disulphide adduct, for which there is no common chemical name. Polyram was previously known as metiram.

Rates of Use:

In all trials benodanil was applied at 1.0 kg a.i./ha. Tridemorph was applied at 0.52 l a.i./ha except in the mixture with benodanil in trials 1, 2, 3 and 4 where 0.26 l a.i./ha was used. Polyram was applied at 1.6 kg a.i./ha and Citowett at 0.175 l /ha was added to benodanil except when the latter was used in a mixture with tridemorph.

RESULTS

Observations:

All trials were visited 5-10 days after application, and it was noted that treatments containing tridemorph had caused a desiccation of yellow rust pustules. This effect was less obvious with the benodanil treatment.

Table 1

Trial Site and Application Details

Trial No.	Location and Cultivar	Date Sown	Growth stage at Application	% Yellow rust at Application	% mildew at Application
1	Yorks. Julia	3.3.74	5-6	3rd leaf 1-5	5
				4th leaf 5-10	20
			8-9	3rd leaf 5-10	5-10
				4th leaf 20-50	5-50
			10.2	3rd leaf 10-50	10
				4th leaf 30	<30
2	Yorks. Wing	22.3.74	10.5	2nd leaf 1-5	0
				3rd leaf 1-5	0
				4th leaf 1-5	0
3	Yorks. Zephyr	28.3.74	5-6	4th leaf 5-50	3
4	Yorks. Zephyr	27.2.74	6-7	3rd leaf 10-20	0
				4th leaf 10-50	1-5
5	S. Lincs. Golden Promise	3.3.75	9-10	3rd leaf 1	trace
				4th leaf 1-20	
6	Wilts. Berac	28.4.75	10.1	3rd leaf 1-5	trace
7	Yorks. Maris Mink	20.3.75	8-9	3rd leaf 1-2	0
				4th leaf 2-5	0
				5th leaf 2-5	0
8	Yorks. Wing	25.2.74	6-7	4th leaf 10-50	0
			8-9	2nd leaf 5-10	0
				3rd leaf 5-10	0
9	Yorks. Julia	20.3.74	4-5	Traces on lower leaves	1-5
			8-9	3rd leaf 1-5	1-10
				4th leaf 1-5	

Table 2

Comparison of applications of benodanil, benodanil + tridemorph and tridemorph + Polyram, on levels of yellow rust at three growth stages (Trial 1)

Treatments	Growth stage at application	% level of yellow rust at G.S. 10.5	% green tissue at G.S. 11.0	Yield kg/ha	Rel. Yield
1. Untreated		43.9	13.1	1560	100
2. Benodanil	5-6	25.2	52.5	2552	156
3. Tridemorph + Polyram	5-6	27.9	33.7	2765	175
4. Benodanil + tridemorph	5-6	28.8	52.5	3049	188
5. Benodanil	8-9	16.2	47.5	2269	144
6. Tridemorph + Polyram	8-9	32.9	43.7	1843	113
7. Benodanil + tridemorph	8-9	13.9	48.7	2552	156
8. Benodanil	10.2	18.5	76.2	1985	125
9. Tridemorph + Polyram	10.2	28.7	30.0	2056	129
10. Benodanil + tridemorph	10.2	22.9	60.0	1985	125
L.S.D. when P = 0.001				254	

Table 3

Comparison of applications of benodanil, tridemorph + Polyram and tridemorph + benodanil on levels of yellow rust in 1974 (Trials 2-4) and 1975 (Trials 5-7)

Trial No. and treatment	G.S. at application	% level of yellow rust	% green tissue at G.S. 11.2	Yield kg/ha	Rel. Yield
TRIAL 2					
1. Untreated	10.5	22.9	15.0	4467	100
2. Benodanil		2.0	66.2	4679	104
3. Tridemorph + Polyram		8.3	36.7	4821	106
4. Benodanil + tridemorph		2.6	60.0	4998	109
TRIAL 3					
1. Untreated	5-6	12.0	29.4	3545	100
2. Benodanil		3.6	52.5	3616	102
3. Tridemorph + Polyram		1.8	63.1	4679	132
4. Benodanil + tridemorph		3.8	69.1	4183	118
L.S.D. P = 0.05				794	
TRIAL 4					
1. Untreated	6-7	7.9	10.6	4225	100
2. Benodanil		1.2	11.2	4402	104
3. Tridemorph + Polyram		1.5	21.2	4793	113
4. Benodanil + tridemorph		2.0	15.3	4651	110
L.S.D. P = 0.05				289	
TRIAL 5					
1. Untreated	9-10	65.0		3691	100
2. Benodanil		15.0		3979	108
3. Tridemorph + Polyram		25.0		3929	106
4. Benodanil + tridemorph		6.3		3929	106
TRIAL 6					
1. Untreated	10.1	50.0		5030	100
2. Benodanil		30.0		5119	102
3. Tridemorph + Polyram		13.8		5406	107
4. Benodanil + tridemorph		12.5		5340	106
Standard error ±				194	
TRIAL 7					
1. Untreated	8-9	14.1		5334	100
2. Benodanil		3.8		5476	103
3. Tridemorph + Polyram		2.2		5618	105
4. Benodanil + tridemorph		2.4		5689	107
Standard error ±				132	

Yellow rust was assessed at G.S. 11 in Trials 2 and 7, G.S. 10.5 in Trials 3 and 4 and G.S. 11.2 in Trials 5 and 6.

Table 4

Evaluation of early and early + late applications for the control of yellow rust in Trial 8

Treatment	Growth stage at application	% level of yellow rust at G.S. 10.5	% green tissue at G.S. 11.2	Yield kg/ha	Rel. Yield
1. Untreated		73.3	0.8	3828	100
2. Tridemorph	5-6	44.6	1.9	4325	113
3. Tridemorph/ tridemorph + Polyram	5-6/ 8-9	21.9	11.2	4892	128
4. Tridemorph/ benodanil	5-6/ 8-9	4.7	21.2	5105	134
L.S.D. when P = 0.001				315	

Table 5

Evaluation of early and early + late applications for the control of yellow rust and mildew in Trial 9

Treatment	Growth stage at application	% level of yellow rust at G.S. 11	% level of mildew at G.S. 11	Yield kg/ha	Rel. Yield
1. Untreated		3.9	27.9	4474	100
2. Tridemorph	4-5	1.9	6.4	4814	107
3. Tridemorph/ tridemorph + Polyram	4-5/ 8-9	0.6	0	5310	119
4. Tridemorph/ benodanil	4-5/ 8-9	0.6	4.5	5084	114
L.S.D. when P = 0.05				405	

DISCUSSION

In trial 1 (Table 2) yellow rust occurred early and was established when the first application was made at G.S. 5-6. In addition, powdery mildew was present at moderate levels. An assessment at G.S. 10.5 showed all treatments gave good reduction of yellow rust levels. The greatest reduction, however, was recorded with treatments containing benodanil applied at G.S. 8-9.

Generally, treatments containing benodanil gave superior control of yellow rust compared with tridemorph + Polyram, and seems to be reflected in the amount of green tissue recorded.

Considerable yield responses resulted from the later application, but the early applications at G.S. 5-6 were clearly superior despite the higher disease levels recorded at G.S. 10.5 and may suggest that reinfection had occurred.

The same treatments were compared in three further trials in 1974 (Table 3). In trial 2, yellow rust was the only disease present and treatments containing benodanil gave better disease control and green tissue retention than tridemorph + Polyram.

In trials 3 and 4, which had lower levels of yellow rust and also some mildew, all treatments again gave good control of yellow rust. However, treatments containing tridemorph gave better green tissue retention and greater yield responses, probably due to the effect of tridemorph against mildew (Jung and Bedford, 1971).

Similar trials were carried out in 1975. Yellow rust developed late and only traces of mildew were recorded. All treatments gave good control of yellow rust, benodanil + tridemorph being the most effective treatment where rust developed to relatively high levels (trials 5 and 6).

Increases in yield were obtained in all 1975 trials, but there were only marginal differences between treatments.

Trials 8 and 9 compared programmes of sequential treatments under conditions of early and prolonged attacks of yellow rust.

In trial 8, tridemorph followed by benodanil gave very good disease control over a long period, resulting in substantial yield increases (Table 4). However, where yellow rust did not develop to high levels and mildew became the dominant disease, (Table 6), tridemorph followed by tridemorph + Polyram gave comparable yellow rust control and a higher yield response, probably due to better control of mildew than that obtained with benodanil.

In all trials, it was noted that treatments containing tridemorph showed a quicker eradicant effect against yellow rust than benodanil alone, although the latter appeared to be more persistent.

It would appear that for most effective disease control, applications should be made at an early stage of yellow rust development. Under conditions of early and prolonged infection, a subsequent application may be necessary.

Where mildew occurs as well as yellow rust, tridemorph + Polyram or benodanil + tridemorph would probably be more beneficial than benodanil alone.

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