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EFFECTIVENESS OF GRANULAR AND SPRAYABLE FORMULATIONS OF FMC 35001, A NEW INSECTICIDE/NEMATICIDE, FOR USE ON AGRICULTURAL CROPS

E.G. Maitlen and N.A. Sladen

FMC Europe S.A., Agricultural Chemical Group
Ch. de la Hulpe 177, B 1170 - Brussels, Belgium

Summary Results of trials conducted throughout Europe on maize, potato, sugar beet and fruits are presented. FMC 35001 applied to the soil as a granule provided excellent control of such soil insects as wireworms, a millipede and a symphylid, and, through translocation to the leaf tissue also controlled such foliar pests as the Colorado beetle and the peach potato aphid. The favourable toxicology and biological activity have also resulted in the development of sprayable formulations.

Résumé Cette communication présente les résultats des essais conduits en Europe sur maïs, pomme de terre, betterave et arbres fruitiers. Appliqué au sol sous forme granulée, le FMC 35001 assure une excellente protection contre les taupins, blaniules et scutigerelle, et, par migration dans le feuillage, contre des insectes aériens comme doryphore et puceron vert. Ses intéressantes propriétés toxicologiques et biologiques ont permis par ailleurs la mise au point de formulations applicables par pulvérisation.

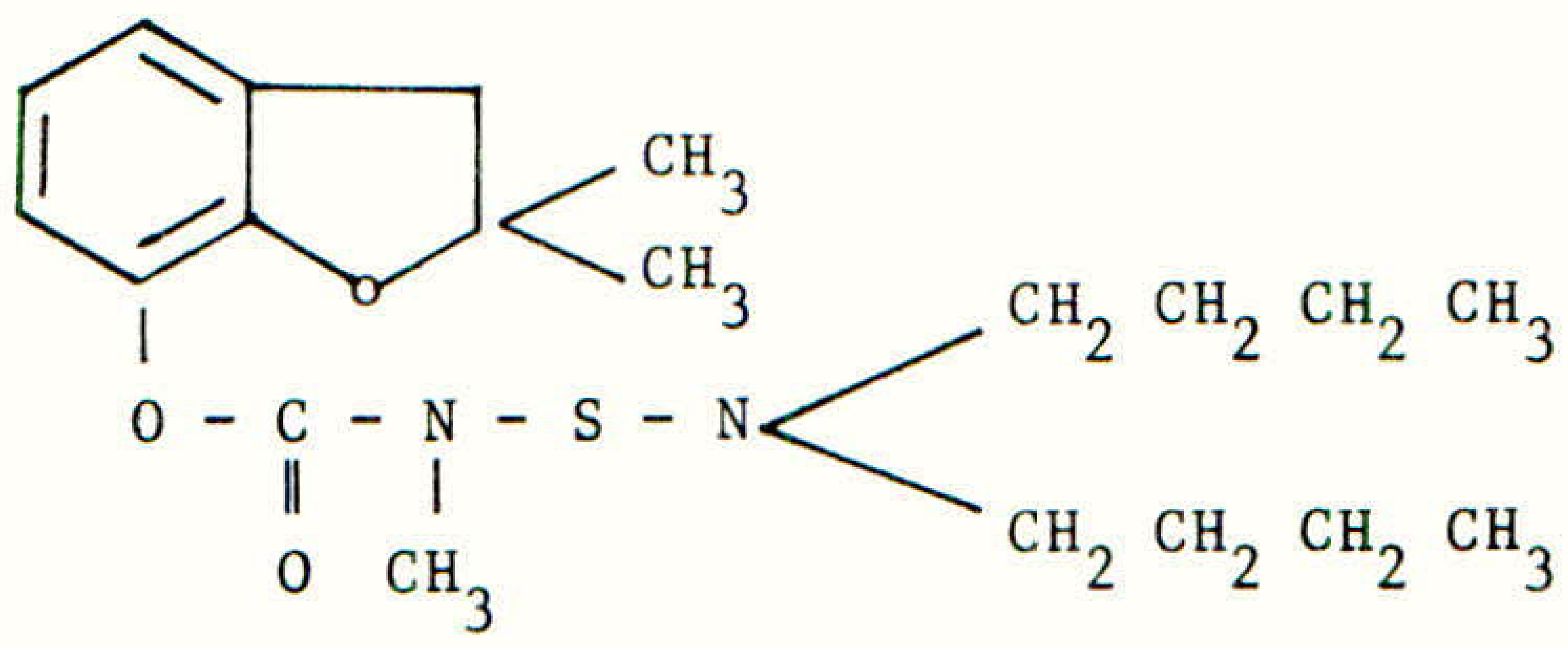
INTRODUCTION

In recent years compounds with substituents attached to the carbamate nitrogen of methylcarbamate insecticides have been synthesized. The intent was to find a new chemical that would maintain the basic insecticidal properties of the methylcarbamates but through modification of the physical properties allow for formulation changes and reduce its inherent toxicity to mammalian species. FMC 35001, the dibutylaminosulphenyl derivative of carbofuran accomplishes these objectives.

FMC 35001 has been tested extensively throughout the world. Outside of Europe, the primary areas and target crops have been the U.S.A. on citrus and alfalfa as a spray; Asia for rice and vegetables as a granule and a spray; Africa and the Mid-East for rice, citrus and olives as a spray; and Latin America for potatoes, coffee, and citrus as a spray. This paper, however, is limited to results obtained in Europe on maize, potatoes, sugar beet and tree fruits.

CHEMICAL, PHYSICAL AND TOXICOLOGICAL PROPERTIES

Structural formula :



Chemical name : 2, 3 dihydro-2,2-dimethyl benzofuran-7-yl [(dibutylamino) thio] methyl carbamate

Molecular formula and weight : $C_{20}H_{32}N_2O_3S$; 380.55

Trademark : Marshal

Physical state : Viscous brown liquid

Vapor pressure : 0.31×10^{-6} mmHg

Solubility : Water - 0.3 ppm at 25°C
Organic Solvents - 〉50%

Formulations : Granules - 5% a.i.
Liquids (e.c.) - 125, 250 g a.i./l
Dusts - 1.5, 2% a.i.

Toxicology :

Table 1

Toxicity of FMC 35001 to mammals, birds and fish

				LD_{50} (mg a.i./kg) Male	Female
Mammals	Rat	acute oral	Tech.	250	185
			25% e.c.	87	130
			5 gran	1200	905
	Rabbit	acute dermal	Tech.	〉 2000	〉 2000
			5 gran	〉 2000	〉 2000

		Formulation	Oral LD_{50}	Dietary LC_{50}
Birds	Pheasant	Tech.	26.2 ppm	1275 ppm
	Mallard	Tech.	8.1 ppm	132 ppm
	Quail	Tech.	81.6 ppm	1073 ppm
			96 - h LC_{50}	
Fish	Bluegill	Tech.	14.9 ppb	
	Trout	Tech.	42.4 ppb	

METHODS

FMC 35001 has been tested in Europe on a wide range of crops with the main emphasis on soil insects infesting maize, potatoes and sugar beets and foliar insects infesting potatoes, sugar beets and tree fruits.
Results from some of the trials conducted from 1976 to 1978 are reported below indicating the performance and the potential use of FMC 35001.

The trials were conducted utilizing a randomized complete block design of three or four replicates. In the trials with granular formulations, the treatments were applied with a commercial granular applicator in the seed furrow at planting to the standard seeding depth for a particular crop. Foliar treatments were applied broadcast to field crops in 250 to 500 l/ha of water with a knap sack sprayer and by a high pressure hand held gun to tree crops in 10 to 15 hl/ha. Dust treatments were applied with a hand dust applicator utilizing 15 to 25 kg of product/ha.

STUDIES WITH GRANULAR FORMULATIONS

Sugar beet

A series of trials were conducted in France in 1977 where soil insects (*Agriotes spp*., *Blaniulus spp*. and *Scutigerella immaculata*) were identified as the major pest problems. The plots were assessed for effectiveness of the treatments 48 to 64 days following the applications by weighing 50 sugar beet roots/plot. The results presented in Table 2 indicate FMC 35001 was as effective as a standard treatment in preventing loss of yield.

Table 2

Effects of treatments on the yield of sugar beet (g/50 roots)

Treatment	Rate (kg a.i./ha)	Site 1	Site 2	Site 3	Site 4	Mean
FMC 35001	0.50	960	686	791	474	727
FMC 35001	0.60	965	695	772	468	725
FMC 35001	0.75	878	718	890	498	746
Carbofuran	0.60	947	620	938	451	739
Untreated	0	714	567	543	306	533

In the preceeding series of trials, FMC 35001 has appeared to provide excellent protection against wireworms (*Agriotes spp*.). An attempt was made during 1978 to confirm this by locating trials on fields that had previously been sown to pasture. Assessment of the plant stand, the number of plants free from wireworm damage and the mean root weight was made 48 days after sowing.

The data in Table 3 indicated that treatment with FMC 35001 not only resulted in a good commercial plant stand but also in reduced feeding damage to the roots and an increased yield almost double the mean weight/root of the untreated plot.

Table 3

Effects of treatments on plant stand, wireworm damage and weight of sugar beet roots

Treatment	Rate (kg a.i./ha)	Plants/ 24 m/row	Undamaged plants (%)	Mean root weight (g)
FMC 35001	0.6	75	53	28
Carbofuran	0.6	57	38	23
Aldicarb	1.0	67	27	23
Untreated	0	49	12	15

Observations were also made on the efficacy against foliar feeding insects. Good control of the pygmy mangold beetle (Atomaria linearis), the flea beetle (*Chaetocnema tibialis*) and the weevil (*Cleonus mendicus*), has been achieved. Early control of aphids has been observed, however, the duration of control has not been determined as the infestations have not been severe during the past few seasons.

Maize

Wireworms (Agriotes spp.) can be a significant problem in maize production particularly when severe infestations occur. FMC 35001, applied in-furrow provided excellent control of wireworms throughout the establishment stage of the crop. The results presented in Table 4 indicate that minimal stand loss occurred during crop establishment.

Table 4

Effects of treatments on stand of maize plants

Treatment	Rate (kg a.i./ha)	Plants/40 m/after 20 days	37 days	Stand loss (%)
FMC 35001	0.3	136	129	5.1
FMC 35001	0.4	124	120	3.2
FMC 35001	0.5	135	133	1.5
Carbofuran	0.6	120	116	3.3
Chlormephos	0.3	104	99	4.8
Untreated	0	76	60	21.1

Yield evaluations were made on trials conducted in Italy (Table 5). Although wireworms were found the incidence of damaged plants in the untreated plots was only about 6%. It was felt the mean increase in yield of 30% from the three sites was attributed to the presence of pest complexes, possibly including nematodes.

Table 5

Effects of treatments on the yield of maize (t/ha)

Treatment	Rate (kg a.i./ha)	Site			Mean
		1	2	3	
FMC 35001	0.5	9.3	11.4	10.6	10.4
Carbofuran	0.5	9.0	10.2	10.5	9.9
Phorate	0.5	8.6	9.4	9.8	9.3
Untreated	0	8.1	8.7	7.3	8.0

Potatoes

FMC 35001 has been treated as an in-furrow application at planting time for the control of Colorado beetle (*Leptinotarsa decemlineata*) and wireworms (*Agriotes spp.*). Depending upon the sowing date and the date of emergence of the Colorado beetle larvae, control of the first generation may be achieved with in-furrow placement of FMC 35001 at 1.5 kg a.i./ha. Activity in the leaf tissue is expected for approximately 70 to 90 days. Table 6 indicates the degree of control of both pests that may be expected from such an in-furrow placement.

Table 6

Treatment	Rate (kg a.i./ha)	Colorado beetle: Larvae/plant after 87 days	Colorado beetle: Leaf damage (%) after 97 days	Wireworms: No tubers damaged after 87 days	Tuber weight 20 plants after 130 days (kg)
FMC 35001	1.0	4.6	7.7	1.0	85.6
FMC 35001	1.5	0	3.1	0.3	88.8
Chlormephos*	1.0	13.3	5.0	1.6	77.1
Untreated	0	27.2	56.9	8.0	63.1

* Azinphos methyl also applied 87 days after sowing. Sowing date March 13

STUDIES WITH SPRAYABLE FORMULATIONS

Potatoes

A number of trials have been conducted throughout Europe with FMC 35001 for the control of Colorado beetle larvae. In northern latitudes where one generation and moderate infestations normally occur, a single spray of FMC 35001 at 0.25 kg a.i./ha, when approximately 25% of the larvae have emerged from the eggs, provided excellent control. In southern latitudes where two generations and extended larval emergence occur, a higher rate of application was required to provide longer residual control. Dust formulations of 1.5 or 2% a.i. have also been equally efficacious as the 12.5 or 25% e.c. formulations. A rate of application from 0.4 to 0.5 kg a.i./ha resulted in good control in Yugoslavia in 1978 (Table 7).

Table 7

% Control of Colorado beetle on potatoes

Insecticide	Formulation	Rate (kg a.i./ha)	Days post treatment				
			4	7	12	20	27
FMC 35001	2% dust	0.30	90.4	99.6	87.7	-	-
FMC 35001	2% dust	0.40	85.3	99.5	91.7	-	-
FMC 35001	2% dust	0.50	99.0	100	100	100	91.6
Dioxacarb	2% dust	0.50	96.5	95.7	99.2	87.4	-
FMC 35001	25% e.c.	0.25	97.7	66.0	-	-	-
FMC 35001	25% e.c.	0.50	99.7	100	99.1	100	93.3
Dioxacarb	50% w.p.	0.50	100	94.8	53.8	-	-

- Trial discontinued and the population sprayed out

Trials are currently being conducted to assess the efficacy against the peach-potato aphid (*Myzus persicae*). Preliminary results presented in Table 8 indicate 0.5 - 0.6 kg a.i./ha is an effective rate when applied in 250-400 l water to potato plants at 75 - 90% row-cover.

Table 8

Effects of treatments on the mean numbers of peach-potato aphid/leaf in 50 leaf samples/plot

Treatment	Rate (kg a.i./ha)	Site			Mean
		1	2	3	
FMC 35001	0.50	1.03	0.25	0.31	0.53
FMC 35001	0.60	0.44	0.95	0.22	0.54
FMC 35001	0.75	0.42	1.29	0.85	0.85
Ethiofencarb	0.50	0.52	0.61	0.36	0.50
Untreated	0	6.67	5.43	2.39	4.83

Tree Fruits

Extensive trials have been conducted on pests infesting apples, peaches plums and pears applying FMC 35001 both as part of a spray program and as a single application. FMC 35001 at a concentration of 50 g a.i./hl of water, and applied at 10-15 hl/ha, provided commercial control of the following pest species : Aphids (*Aphis pomi*, *Dysaphis plantaginea*, *Hyalopterus pruni*, *Myzus persicae*), fruit tree trotrix (*Archips podana*), apple midge (*Dasyneura mali*), codling moth (*Laspeyresia pomonella*), green leafhopper (*Empoasca flavescens*), peach twig borer (*Anarsia lineatella*), plum sawfly (*Hoplocampa flava*), oriental fruit moth (*Grapholitha molesta*) and the scales, *Diaspis pentagona* and *Quadraspidiotus perniciosus*.

Observations were made on the effects of the above spray programs on mites. Populations of *Panonychus ulmi* and *Tetranychus urticae* were maintained below economic threshold levels in all trials. Adult mites appeared to be controlled by contact and residual activity, although no ovicidal activity was observed. Commercial control of apple blister moth (*Leucoptera scitella*), apple leaf miner (*Lithocolletis blancardella*) and pear psylla (*Psylla pyricola*) was not achieved.

CONCLUSION

The results presented indicate that FMC 35001 applied to the soil as a granule at planting controlled a range of economic soil and foliar pests with particularly strong activity against wireworms. The favourable mammalian toxicology and the satisfactory biological performance of the sprayable formulation allows for safe, efficient control of major foliar pest species.

Acknowledgement

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TRIADIMENOL SEED TREATMENTS FOR THE CONTROL OF CEREAL DISEASES

A. Wainwright, A.C. Rollett and D.B. Morris

Bayer U.K. Limited, Agrochem Division, Eastern Way,
Bury St. Edmunds, Suffolk, IP32 7AH

Summary Trials conducted between 1976-1979 showed triadimenol, a broad spectrum fungicide of low toxicity, to be active against seed-borne and foliar pathogens of cereals when used as a seed treatment at a rate of 37.5 g/100 kg seed. Effective control of the smuts, *Ustilago nuda*, *U. avenae* and *Tilletia caries*; leaf stripe, *Pyrenophora graminea*, in spring barley; net blotch, *P. teres*; foot rot, *Cochliobolus sativus*; oat leaf spot, *P. avenae* and seedling blight, *Leptosphaeria nodorum* was exhibited. Improved control of seedling blight, *Micronectriella nivalis*, was obtained by the addition of fuberidazole.

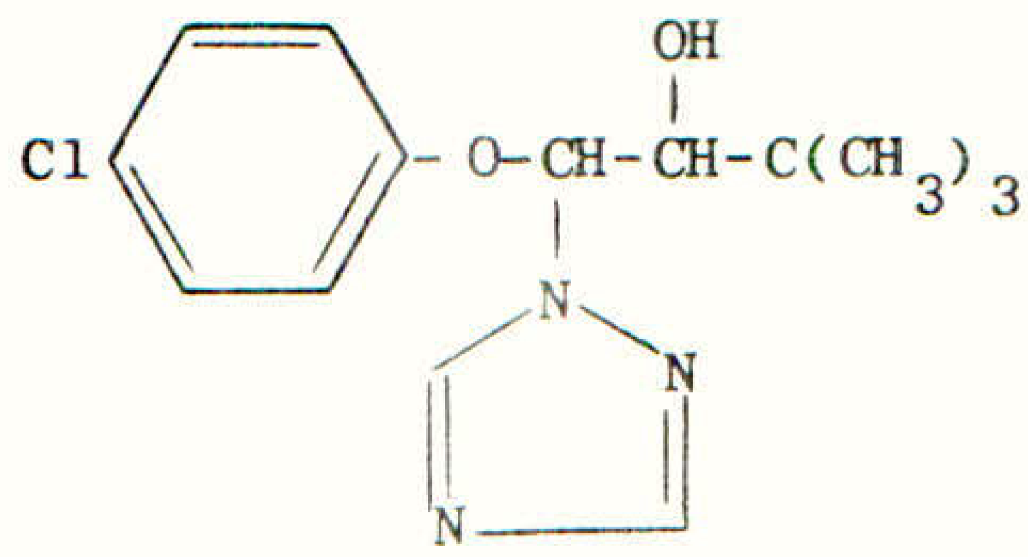
Systemic activity was also demonstrated against mildew, *Erysiphe graminis*, leaf blotch, *Rhynchosporium secalis* and the rusts, *Puccinia spp*. In the case of diseases occurring late, in particular the rusts, and in autumn sown crops, a foliar fungicide application may be warranted, though in spring crops triadimenol seed treatments gave season-long protection against mildew and leaf blotch.

Résumé Plusiers essais conduits pendant les années 1976-1979 ont révélé que triadimenol, un fongicide avec un large champ d'activité et peu de toxicité, est très efficace dans la lutte contre les agents pathogènes transmises par la semence et les maladies du feuillage de céréales suivant la désinfection de la semence à la dose de 37.5 g/100 kg de semence. Une bonne efficacité contre les charbons (*Ustilago nuda*, *U. avenae* et *Tilletia caries*); l'helminthosporium de l'orge (*Pyrenophora graminea*); les taches brunes (*P. teres*); la maladie du pied (*Cochliobolus sativus*); l'helminthosporium de l'avoine (*P. avenae*); et la nielle des jeunes plantes (*Leptosphaeria nodorum*) a été constatée. Par l'addition de fuberidazole, une lutte meilleure contre la nielle des jeunes plantes (*Micronectriella nivalis*) peut être obtenue.

Une activité systémique contre l'oidium (*Erysiphe graminis*); les taches des feuilles (*Rhynchosporium secalis*); et les rouilles (*Puccinia spp.*) a été aussi aperçue. En cas des contaminations plus tard, particulièrement les rouilles et autres maladies des cultures semées en automne, une application d'un fongicide au feuillage peut être nécessaire, mais une désinfection de la semence de céréales de printemps avec triadimenol a donné une défense pendant toute la saison contre l'oidium et les taches des feuilles.

INTRODUCTION

Triadimenol, 1-(4-chlorophenoxy)-3,3-dimethyl-1-(1,2,4-triazol-1-yl)butan-2-ol, is a new systemic fungicide especially suited for use as a seed treatment for autumn and spring sown cereals. It is a member of the triazole group of fungicides (Kaspers et al, 1975) and has the following structural formula:



Appearance: colourless, microcrystalline powder with a faint, unspecific odour

Melting point: 112°C

Vapour pressure: 10^{-5}m bar Hg at 20°C

Solubility: 120 mg/l in water at 20°C, higher in organic solvents

Toxicology: LD_{50} rats (oral) male and female, 1161/1105 mg/kg body weight
LD_{50} quail (oral) >10,000 mg/kg body weight
Feeding studies over 3 months with dogs and rats, male and female, showed a no-effect dose of 600 ppm.

Triadimenol is very closely related structurally to triadimefon, reported previously (Morris et al, 1977; Rowley et al, 1977) and it has been identified within fungal and plant tissues as a metabolite of triadimefon (Clark et al, 1978; Buchenauer, 1979). The mode of action appears to be similar to other members of the triazole group in that the biosynthesis of ergosterol is affected in susceptible fungal strains (Buchenauer, 1978). Triadimenol has been shown to be biologically active in vivo against a number of fungal diseases in plants, the spectrum of activity being particularly useful in the control of seed-borne and foliar diseases of cereals (Frohberger, 1978; Trägner-Born and Van den Boom, 1978).

In the U.K. trials work has been carried out principally on formulations containing the additional fungicide fuberidazole, 2-(2-furyl) benzimidazole, for improved control of seedling blight and foot rot (Micronectriella nivalis). In view of the specific effect of fuberidazole (Schuhmann, 1967), the contribution of this component can be discounted in all trials except those specifically examining the effect against M. nivalis.

This paper summarises the evaluation of triadimenol seed treatments during 1976-1979 for disease control in wheat, barley, oats and rye.

METHODS AND MATERIALS

Dry seed treatments were applied to achieve rates of 30, 37.5 and 50g triadimenol/100 kg seed. During 1976 and 1977 the formulation contained triadimenol (25% w/w) with fuberidazole (4% w/w). In 1978 and 1979 the fuberidazole component was reduced to 3% w/w, and for the lower rate, triadimenol (15% w/w) with fuberidazole (2% w/w) was used. Hence the weights of fuberidazole corresponding to 30, 37.5 and 50g triadimenol were 4-4.8, 4.5-6, 6-8 g/100 kg seed respectively. Where appropriate, triadimenol (15% w/w) alone was tested.

A standard seed treatment of phenylmercury acetate (PMA) with carboxin was used for trials aimed to assess the effects against seed-borne pathogens. Against foliar pathogens, the standard was ethirimol (58% w/v) applied as a seed treatment, or in some trials in 1979, triadimefon (25% w.p.) applied as a foliar spray. A primary treatment of an organomercury, usually PMA, was applied to the seed. In Tables 3-6 dealing with foliar diseases, the fuberidazole and organomercury components are not listed.

Seed-borne pathogens Between 1976-79, 35 replicated trials were conducted, using a randomised block design and plots of 1m x 1m. The sowing rate was 20-50 g/m^2 depending upon the seed infection level, and the seed batch for each plot was individually treated for a standard 2 minutes. All trials were sown by hand at Elm Farm Trials Station near Bury St. Edmunds, Suffolk, the soil type at this site being a sandy clay loam. The infected seed used in the trials resulted from natural field infections with the exception of bunt (*Tilletia caries*) which was artificially inoculated by dusting healthy seed with fungal spores (2g spores/kg seed). Trials were carried out on:

Spring barley - loose smut, *Ustilago nuda*; leaf stripe, *Pyrenophora graminea* (= *Drechslera graminea*); net blotch, *Pyrenophora teres* (= *Drechslera teres*); foot rot, *Cochliobolus sativus* (= *Helminthosporium sativum*).

Winter barley - loose smut, *Ustilago nuda*; leaf stripe, *Pyrenophora graminea* (= *Drechslera graminea*); net blotch, *Pyrenophora teres* (= *Drechslera teres*).

Winter wheat - loose smut, *Ustilago nuda*; bunt, *Tilletia caries*; seedling blight and foot rot, *Micronectriella nivalis* (= *Fusarium nivale*) and *Leptosphaeria nodorum* (= *Septoria nodorum*).

Spring oats - leaf stripe, *Pyrenophora avenae* (= *Drechslera avenae*); loose smut, *Ustilago avenae*.

Winter rye - seedling blight, *Micronectriella nivalis* (= *Fusarium nivale*).

Trials were assessed by counting diseased and healthy plants or tillers in each plot and percent control figures calculated from these data. Normally, trials were assessed at growth stage (GS) 75-85 (Zadoks *et al*, 1974), though *P. teres* and *C. sativus* were assessed between GS 32 and 47, and *P. avenae*, *L. nodorum* and *M. nivalis* were assessed at GS 11-12.

Foliar pathogens A total of 63 replicated trials (30 spring barley cv. Wing, Golden Promise, 15 winter barley cv. Maris Otter, Astrix, 13 winter wheat cv. Maris Ranger, Hobbit, Sportsman, 1 spring wheat cv. Maris Butler, and 4 spring oat cv. Astor, Selma) were carried out between 1977-1979 using a randomised block design with plots of 15m x 1.5m. Non-infected seed was treated in a rotating drum for 2 minutes and trials were drilled with an 'Oyjord' plot drill at a normal rate of 140 kg/ha. During 1979, 21 non-replicated trials were drilled with spring barley (cv. Georgie and Wing) using an 'Amazone D7-25' commercial drill fitted with Suffolk coulters. Seed was treated using a 'Plantector' seed treating machine and drilled at 140 kg/ha into plots of 150m x 20m.

Crop emergence was assessed by counting seedlings at GS 12. Disease control was measured by assessing the percentage infected area on the uppermost three leaves, green leaf area being similarly assessed by recording the percentage green tissue. Foliar diseases assessed were mildew (*Erysiphe graminis*) of wheat, barley and oats, leaf blotch (*Rhynchosporium secalis*) of barley, yellow rust (*Puccinia striiformis*) and brown rust (*P. hordei*) of barley. Yield measurements were obtained using a 'Claas Compact 25' combine harvester and corrected to 14% moisture content. Grain quality was assessed in terms of 1000 grain weight and grain size.

Table 1

Control of seed-borne diseases expressed and medians of % control or % increase in emergence (in parenthesis)

Crop and disease pathogen	Treatment-g a.i./100 kg seed: Triadimenol 30	Triadimenol + (fuberidazole) 30+ (4-4.8)	37.5+ (4.5-6)	50+ (6-8)	PMA + carboxin 200-225†	% infected tillers/plants on untreated	No. of trials
Spring barley							
U. nuda		100	100	100	100	13	3
P. graminea		100	100	100	100	12	5
P. teres		92	98	96	97	11	1
C. sativus		98*	97*	98*	91	93	1
Winter barley							
U. nuda		100	100	100	100	2	3
P. graminea		0*	15*	0*	100	26	3
P. teres			100	100	100	9	1
Spring oats							
P. avenae		94	100*	97*	94	9	4
U. avenae		100	100	100	100	5	3
Winter wheat							
U. nuda		100	100	100	100	1	2
T. caries		99	100	100	100	66	4
L. nodorum	98	86	88	85	93	24	1
	(126)	(123)	(121)	(123)	(116)	(370 plants/m^2)	
M. nivalis	58	99*	99*	99*	66	66	1
	(343*)	(392)	(383)	(371)	(390)	(115 plants/m^2)	
Winter rye							
M. nivalis	76*	99	98	100*	97	31	1
	(139*)	(153)	(158)	(157)	(157)	(380 plants/m^2)	

* significantly different to standard at P = 0.05   † given as rate of formulation

Assessment data from all replicated trials were analysed statistically and significances are indicated in the tables of results. Results on seed-borne diseases, emergence and spring barley mildew control, green leaf area and yield are expressed as medians. Control of individual diseases is expressed as a percentage relative to the untreated. Trials are numbered using a prefix to indicate the appropriate Bayer regional centre; A - Elm Farm Trials Station, Suffolk, C - Scotland, E - Eastern, M - Midland, N - Northern, S - Southern, W - Western.

RESULTS

Seed-borne pathogens All seed-borne disease assessments were statistically significant and differences between the triadimenol treatments and the standard at P = 0.05 are indicated (Table 1). In one trial against *P. avenae*, the control given by the standard was only 41%, though normally the results for seed-borne disease trials were remarkably uniform; therefore, where more than one set of results are available, a median figure is quoted. Successful infection by the seedling blights *L. nodorum* and *M. nivalis* tends to be weather dependent and several trials are not reported as clear symptoms did not develop.

Foliar pathogens In these trials using non-infected seed, triadimenol treatments had little overall effect on plant stand (Table 2), and in addition to trials reported here, small plot cultivar compatibility trials confirmed the safety when applied to 14 winter wheat, 4 winter barley, 2 winter oat, 14 spring barley, 3 spring wheat and 3 spring oat cultivars. Disease control is shown in Tables 3, 4 and 5 for trials where higher levels of disease were present, though frequently such levels were not present until late in the growing season. All assessments reported were statistically significant with the exception of the brown rust assessments of winter barley, A7/78, S6/79 (Table 5) and differences between the triadimenol treatments and the standard at P = 0.05 are indicated. The majority of foliar disease trials were made on spring barley and data are summarised as medians (Table 6). The medians for mildew control were calculated from those trials with >2% mildew, and relative green leaf area from trials with <95% green leaf on untreated plants at the time of assessment. The yield and grain quality medians represent all trials harvested in 1977 and 1978 irrespective of disease level: the median mildew level in these trials was 1.7%. At the time of writing, yield data for 1979 trials are not available.

Table 2

Relative crop emergence - medians of all trials 1977-79 with non-infected seed

		Non-replicated	Replicated				
Treatment	g a.i./100 kg seed	Spring barley	Spring barley	Winter barley	Winter wheat	Spring oats	Spring wheat
triadimenol	30		98	99	101	102	96
+ fuberidazole	4-4.8						
triadimenol	37.5	94	98	100	99	100	102
+ fuberidazole	4.5-6						
triadimenol	50		96	98	96	101	101
+ fuberidazole	6-8						
PMA	~2.2		102	102	100	100	123
PMA	~2.2	96	102	104			
+ ethirimol	390						
Untreated. no. plants/m row		41	61	50	41	49	65
No. of trials		19	29	15	10	3	1

Table 3

Foliar disease control in replicated spring barley trials 1977-1979 - mean % control on top 3 leaves

		Mildew									Yellow rust				
Trial no/year		S1/77	W1/77	E1/78	E2/78	M1/78	A1/79	C1/79		M2/79	N1/77	M1/78	A2/78	E3/78	M3/78
Date drilled		5/4	13/4	3/4	7/4	17/4	21/4	24/4		22/4	6/4	17/4	7/4	5/4	17/3
Assessment GS		58	75	75	75	85	76	32	75	85	85	85	75	77	60
Assessment date		7/7	15/7	11/7	14/7	24/7	26/7	2/7	13/8	16/7	22/7	24/7	24/7	26/7	5/7
Treatments	g a.i./100 kg seed														
triadimenol	30	91*	94	86*	92*	65	75*	91	71*	77*	63*	0	18	39	57*
triadimenol	37.5			85*	97*	78*	80*	90	84*	73*		10*	19	60	45*
triadimenol	50	73	99	87*	97*	87*	85*	95	90*	81	75*	42*	28	79	61*
ethirimol	390	59	93	36	57	32	25				0	0	14	0	0
triadimefon	125†							-	100	98					
% Infection on untreated		14.4	11.7	6.4	7.2	14.6	4.9	6.9	53.3	12.6	3.0	2.2	5.1	10.4	3.9

Table 4

Foliar disease control in non-replicated spring barley trials 1979 - mean % control on top 3 leaves

		Mildew												Leaf Blotch		Yellow Rust
Trial no		A3	C2	E4	M4		N2	N3	S2		S3	S4	W2	C3	W3	S4
Date drilled		14/5	25/4	12/4	13/3		20/4	20/4	18/4		16/4	19/4	6/4	26/4	17/4	19/4
Assessment GS		83	75	59	37	85	83	75	41	83	39	69	69	75	54	69
Assessment date		30/7	14/8	20/7	15/6	11/7	27/7	16/7	21/6	23/7	21/6	11/7	11/7	24/8	5/7	11/7
Treatments	g a.i./100 kg seed															
triadimenol	37.5	88	92	88	100	89	95	94	99	88	100	99	99	85	99	96
ethirimol	390	49	29	23	46	46	46	43	69	0	94	35	33	0	26	42
% Infection on untreated		18.3	21.3	6.7	4.0	47.0	11.8	8.5	5.1	23.5	4.1	12.5	13.8	5.1	20.2	9.6

† 125g a.i./ha applied as a foliar spray at GS 32

* Treatment significantly different to standard at P = 0.05

Table 5

Percent disease control (mean of top 3 leaves) in replicated trials on winter barley, winter and spring wheat and spring oats

		Mildew Winter Barley				Mildew Winter Wheat			Mildew Spring Oats			Mildew Spring Wheat	
Trial no/year		E5/79	M5/79	N4/79	W3/79	A9/78	E6/79	N5/79	A5/78	N6/78	S5/78	A6/79	
Date drilled		16/10	2/10	5/10	4/10	10/10	3/11	1/11	7/4	4/4	20/4	21/4	
Assessment GS		75	32	70	22	75	59	83	77	71	58	68	75
Assessment date		28/6	22/5	4/7	6/12	14/7	6/7	24/7	7/8	14/7	5/7	12/7	24/7
Treatments	g a.i./100 kg seed												
triadimenol	30	89	95	33*	81		70	21*	67	85	94	93	84
triadimenol	37.5	90	94*	42	100	32	87	57	71	90	93	96	95
triadimenol	50	93	99	35*	100	53	97	65	84	97	93	99	81
triadimefon	125†	93	100	58			96	80					
% Infection on untreated		21.9	6.1	17.8	5.8	10.0	7.4	4.3	4.9	6.3	10.4	3.5	3.7

		Leaf Blotch Winter Barley							Brown Rust Winter Barley	
Trial no/year		N7/77	A7/78	E7/79	E8/79	N6/79	W5/79		A7/78	S6/79
Date drilled		22/10	10/10	10/10	9/10	6/10	4/10		10/10	13/10
Assessment GS		30	30	83	80	77	30	73	75	85
Assessment date		10/5	19/4	5/7	27/6	10/7	10/5	26/6	28/6	26/6
Treatments	g a.i./100 kg seed									
triadimenol	30	87	51	46	62	65	26*	2	76	23
triadimenol	37.5		52	39	58	45*	59*	7	59	18
triadimenol	50	96	44	53	65	75	40*	16	20	22
triadimefon	125†			54	55	73	82	24		14
% Infection on untreated		4.3	14.5	11.1	9.8	8.3	16.4	41.9	23.8	5.5

† 125g a.i./ha applied as a foliar spray at GS 32 * Treatment significantly different to standard at P = 0.05

Table 6

Spring barley trials - Summary (medians) of % mildew control and relative green leaf area, yield, grain weight and size

Treatment	g a.i./100 kg seed	Non-replicated 1979 Mildew control early GS 32-69	Non-replicated 1979 Mildew control late GS 75-85	Replicated 1977-1979 Mildew control GS 58-85	Replicated 1977-1979 Relative green leaf area GS 68-85	Replicated 1977-1978 Yield	Replicated 1977-1978 1000 Grain weight	Replicated 1977-1978 Grain >2.8mm
triadimenol	30			86	115	102	102	104
triadimenol	37.5	99	89	84	115	102	102	105
triadimenol	50			87	119	103	102	103
ethirimol	390	42	46	36	103	100	100	98
triadimefon	125†			98	112			
Level on untreated		3.5%	14.8%	7.1%	68%	5689 kg/ha	38.7g	57.2%
No. of trials		8	9	15	21	18	18	18

† 125g a.i./ha applied as a foliar spray at GS 32

DISCUSSION

The non-systemic organomercuries have been used for many years as cereal seed treatments to control seed-borne pathogens and recently considerable interest has been shown in less toxic replacements. In field experiments, new seed treatments based on triadimenol gave complete control of the loose smuts of wheat and barley which are not controlled by organomercuries alone and for which additives such as carboxin are required. Tolerance to organomercury is known in P. avenae, and triadimenol treatments gave significantly better control of both this pathogen and C. sativus than the standard organomercury/carboxin treatment. For consistent control of bunt in wheat, trials have indicated that a rate of at least 37.5g triadimenol/100 kg seed is required.

Although good control of leaf stripe was given in spring barley this was not the case in the winter crop. The reason for this anomaly is not understood, but in order to obtain fully effective control of this pathogen, new formulations with additional active ingredients are being tested. Formulations containing triadimenol alone gave useful control of foot rot (M. nivalis) though clearly the effect was enhanced by the addition of fuberidazole to give significantly better control of post-emergence symptoms than the standard treatment.

Triadimenol treatments were compatible with all cultivars tested, though some delay in emergence was observed under difficult seedbed conditions particularly if seed was deep drilled, or the soil was hard or compacted. With non-infected seed there was little overall effect on plant stand (Table 2), though where certain pathogens e.g. M. nivalis were present on the seed, substantial increases in braird were obtained.

In spring crops in particular, triadimenol gave impressive control of mildew (Tables 3 and 4). There were indications of a response to rate which was well illustrated by C1/79 where under high disease pressure the lower rate became relatively less effective between 12 and 16 weeks after drilling. Generally, mildew control appeared better in the non-replicated large plot trials on barley, possibly due to there being little or no interference between plots as experienced in small plot replicated trials, where the effect of a treatment may be underestimated (Jenkyn et al, 1979). In autumn sown cereals, mildew protection lasted throughout the winter and early spring and in some trials was still evident in May/June, a period of some 30-35 weeks after drilling (Table 5).

Leaf blotch occurred in two spring barley trials (Table 4), and good control was recorded, though in the autumn sown trials results became unreliable towards June. In winter barley, this is probably related to inadequate persistence during late spring when climatic conditions frequently favour spread of this disease.

Triadimenol showed activity against the rusts in several trials, the effect being greatest in the spring barley crop. Yellow rust occurred infrequently and although control of late attacks was variable, in the non-replicated large plot trial S4/79, excellent control of the disease was obtained. Brown rust, on the other hand, is more difficult to control, usually occurring late in the season and building up rapidly when temperatures are higher. Seed treatments may have delayed the build-up of this disease; however, they could not be considered sufficiently effective at this stage.

Disease incidence in replicated spring barley trials taken to yield was only 1.7% mildew as a median but this resulted overall in a small yield response. Some individual trials have given large increases as in a large plot trial made in 1978 on spring barley cv. Wing, when early mildew establishment and the absence of inter-plot interference led to a yield increase of 18.5% with 37.5g triadimenol/100 kg seed.

With a broad spectrum of activity and systemic movement within the plant, triadimenol seed treatments offer unique control of the major seed-borne and foliar diseases affecting cereals. The persistence against mildew and leaf blotch is very good, but late attacks of these diseases and particularly rusts, when the level of fungicide in plant tissues is reduced, may well require a foliar applied spray in addition, especially in the case of autumn drilled crops where the length of the growing season may extend to 10 months.

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