THE EFFECT OF BENODANIL ON SNOW ROT (TYPHULA INCARNATA) IN WINTER BARLEY

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ABSTRACT

Small plot and farmer usage trials carried out since autumn 1982 have shown that benodanil gives excellent control of snow rot as measured by sclerotia production, down to the lowest rate tested (0.25 kg a.i./ha). Single sprays of benodanil applied from late October to mid-January have given consistently good results. Triadimefon applied at the same timings has given only moderate control and has resulted in large number of sclerotia being returned to the soil. However, the benefits of broad spectrum fungicides have been realised particularly where Fusarium developed in combination with Typhula.

Prospects for the long-term control of this disease are discussed.

INTRODUCTION

The occurrence of snow rot (Typhula incarnata) has been reported on cereals and grasses in many countries; severe infections have often been associated with harsh winter conditions and in particular when crops have encountered extensive periods under snow cover (Lehmann 1965 a,b, Jackson and Fenstermacher, 1969). Winter barley is particularly susceptible and recent intensification of the Scottish winter barley acreage together with the occurrence of severe winters have probably been contributory factors to a recent build-up of disease especially in the Northern region. A measure of the significance of the disease may be gained by advisory reports from the North of Scotland College of Agriculture which indicate that few winter barley fields remained uninfected, and an area in excess of 75 hectares has had to be ploughed in as a result of severe infections which led to plant loss (Wale, 1984). Reports of infection in Southern England are also widespread, although the implications for yield loss are less severe under such relatively mild overwintering conditions.

Infected crops return large numbers of sclerotia to the soil. It has been suggested that sclerotia are likely to be the major source of infection since mycelial growth across soil is limited and basidiospores are of no practical importance. The same worker showed that sclerotia do not germinate unless they are close to the soil surface and that burial for 6 months does not markedly impair viability (Lehmann, 1965 b). Provided sclerotia can remain viable for periods in excess of 12 months therefore, ploughing would not necessarily provide a solution since successive ploughings may expose following barley crops to attack via germinating sclerotia.

Typhula incarnata is often reported in association with Fusarium species. Since Fusarium is commonly found in parts of Scotland, disease control strategies should perhaps take account of both diseases.

Benodanil is a basidiomycete-specific fungicide which was introduced to the UK in 1973 for the control of cereal diseases (Frost & Jung, 1973). It is now available for the control of several rust species and is sold under the trade name 'Calirus'.

MATERIALS AND METHODS

Small plot replicated (x 4) randomised block and large plot farmer usage trials are reported. The treatments in small plot trials were applied by knapsack sprayers using 250 l/ha water and 12 Pascals pressure. The large plot unreplicated trials utilised farm machinery operating in the range 225-340 l/ha and 11.5-13.5 Pascals pressure.

The following active ingredients have been used in the trials: benodanil (50% w.p),carbendazim (50% w.p and s.c.), chlorothalonil (50% s.c.) fenpropimorph (75% e.c.), maneb (80% w.p), prochloraz (40% e.c.), propiconazole (25% e.c.), tridemorph (75% e.c.) and vinclozolin (50% w.p.). Some benodanil treatments have included a wetting agent ('Citowett', 99 - 100% alkylarylpolyglycol ether); this is referred to as 'wetter'. A formulated (w.p.) mixture of tridemorph 9.4% + carbendazim 3.8% and maneb 40% ('Cosmic') was used extensively in the 1983/84 trials; in the interest of brevity this is referred to as T+C+M in the tables and as formulated tridemorph + carbendazim + maneb in the text.

The effects of snow rot are non-characteristic and, for example, may easily be confused with Fusarium. In order to obtain an objective assessment, the number of sclerotia of T.incarnata were counted. In most trials the total number of sclerotia on the aerial portion of 25 randomly selected plants were counted per plot (100 plants per treatment). Results are expressed as number of sclerotia per 100 plants, percent control relative to the untreated, and percent number of plants infected. In the one trial where there was a severe combined infection of Typhula and Fusarium, plants were often matted and sclerotia could not be counted on individual plants. Snow rot was assessed on a 0-3 scale where 0 = 0, 1 = 1-5, 2 = 5-10 and 3 = 10 sclerotia visible on the plant surface per 6.4 cm^2 (per square inch). Differences in green tissue apparent between plots, for whatever reason, were assessed as overall percent green tissue relative to the untreated plot, which was 100%.

Ear populations were assessed by counting ears in 9 double row lengths totalling $1m^2$ per plot. Yields, where taken, were obtained using a 'Claas Compact 25' small plot combine harvester; grain yield was corrected to 15% moisture. Unless stated otherwise, statistical analysis was performed using Duncan's test; figures in tables with the same suffix letter are not significantly different at the 5% level of probability.

RESULTS

A field scale small plot screen laid down in the autumn of 1982 in Gloucestershire indicated that several compounds had activity against snow rot (Table 1). Of the compounds tested,triadimefon gave good control, but benodanil + wetter totally prevented sclerotia production.

The efficacy of benodanil against snow rot was confirmed in a series of small plot trials laid down in the autumn of 1983 in England and especially Scotland. On three sites snow rot was the only disease to develop to significant levels (Table 2). The results show that benodanil gave excellent control of snow rot sclerotia at all rates tested (down to 0.25 kg a.i./ha) and that the use of wetter was not necessary to maintain control. Triadimefon, in contrast to the 1982/83 trial, gave only moderate control except at one site where the infection was low on a 6-row variety (cv Pirate: Tarland). Assessments of plant infection frequency emphasised the difference in performance of benodanil and triadimefon. Snow rot was very damaging at the most northerly site (Banff) and sclerotia control was associated with substantial increases in overall green tissue levels. Despite the absence of other foliar diseases at this site, benefits of broad spectrum fungicides were realised. Formulated tridemorph+carbendazim+maneb alone gave increased green tissue levels but due to its inability to control snow rot, higher numbers of sclerotia were seen on these plots. The tank mixture of formulated tridemorph+carbendazim+maneb plus benodanil and wetter gave optimum disease control and green tissue retention. Triadimefon also showed the benefits of broad spectrum activity but did not significantly reduce sclerotia production.

The importance of broad spectrum fungicidal activity was emphasised at the Aberfeldy site (Table 3) where a severe mixed infection of T.incarnata and Fusarium developed. Pink mycelium of Fusarium and very high numbers of Typhula sclerotia were visible (the presence of F.nivale was confirmed at the Scottish Crop Research Institute). Although benodanil gave exceptional sclerotia control, the yield benefits were not realised due to the presence of Fusarium. The broad spectrum mixture of formulated tridemorph+carbendazim +maneb plus benodanil and wetter gave excellent overall disease control, leading to a 27% increase in yield (Table 3). Again triadimefon showed the benefits of broad spectrum activity and associated yield response but gave poor control of Typhula allowing very large numbers of sclerotia to be returned to the soil (approximately 5,000/m^2). Vinclozolin gave better control of sclerotia than triadimefon at this site.

Six farmer usage trials further confirmed the activity of benodanil against snow rot (Table 4). Benodanil was applied to part-fields in addition to the farmer's standard fungicide programme, which was applied to the entire field. The 1.0 kg a.i./ha rate totally prevented sclerotia production at 4 sites; the lower 0.5 kg a.i./ha rate performed well at the two sites where it was tested. None of the overall farmer-applied treatments prevented sclerotia production, which in two cases included triadimenol seed treatment. The highest infection in the Scottish farmer-applied trials (Tarves) followed a triadimenol seed treatment and a triadimefon spray; the benodanil spray superimposed on this programme totally prevented sclerotia production.

Table 1: Chemical screen against snow rot. Hatherop, Gloucestershire.cv Sonja

Treatment (3.12.83: GS 23-25)	g a.i./ha	sclerotia/ 100 plants	(early May) % control
Untreated	-	1500	-
carbendazim (s.c.)	250	1896 +	0
prochloraz	400	1556 +	0
T+C+M	2128	1280 +	15
tridemorph	525	1100	27
fenpropimorph	750	1052	30
chlorothalonil	1000	1020 +	32
propiconazole	125	824 *	45
triadimefon	125	296 **	80
benodanil + wetter	1000+175	0 ***	100

+ only 2 replicates assessed; results not subjected to statistical analysis.
*,**,***: significantly different from untreated at 5%, 1% and 0.1% level
LSD's are 676,924 and 1260 sclerotia respectively.

Table 2: Control of snow rot on sites where no other disease developed

Site:		Milton, Oxon		Tarland, Grampian		Banff, Grampian			MEAN		
Variety:		Igri		Pirate		Igri					
Date sprayed:		18.01.84		02.12.83		29.11.83					
Date assessed:		09.04.84		03.05.84		29.02.84	02.05.84				
G.S. assessed:		31		32-37		26	32				
Variable:		Sclerotia	%PI	Sclerotia	%PI	GT	Sclerotia	%PI	Sclerotia	% Control	% PI
Treatment	g a.i./ha										
Untreated		3636 e	68	243 c	20	100	1565 b	84	1815	-	57
benodanil + wetter	250+ 175	472 abc	4	11 a	5	119	301 c	28	261	86	12
benodanil + wetter	500+ 175	932 abcd	28	10 a	3	118	319 c	17	420	77	16
benodanil + wetter	750+ 175	348 ab	16	4 a	0	117	3 c	2	118	93	6
benodanil + wetter	1000+ 175	172 a	16	3 a	2	117	6 c	2	60	97	7
T+C+M	2128	3412 c	48	147 abc	24	121	3343 a	95	2301	27	56
T+C+M + benodanil + wetter	2128+1000 + 175	212 a	12	8 a	2	124	35 c	6	85	95	7
triadimefon [1]	125	2180 cde	60	12 a	13	123	872 bc	53	1021	44	42
vinclozolin	500	2500 de	16	183 bc	29	107	1661 b	86	1448	20	44
benodanil	1000	4 a	0	2 a	2	120	0 c	0	2	100	1

1: 3 replicates only at Banff: %PI = % number of plants infected: GT = % green tissue relative to untreated

Table 3: Control of T.incarnata and Fusarium. Aberfeldy,Tayside. cv Igri

Date assessed:		23.02.84	23.03.84	23.03.84	11.07.84	
GS assessed:		26	30	30	83	
Variable:		% Green Tissue		Sclerotia(0-3)	Ears/m^2	Yield t/ha
Treatment [1]	g a.i./ha					
Untreated		100	100	2.75	548 ab	5.74 ab
benodanil [2]	250	105	114	0.25	551 ab	6.10 ab
benodanil [2]	500	107	114	0	508 a	5.89 ab
benodanil [2]	750	103	115	0	476 a	5.67 ab
benodanil [2]	1000	106	113	0	536 a	5.54 a
T+C+M	2128	183	262	2.25	666 bc	6.67 bc
T+C+M + benodanil [2]	2128 1000	247	500	0.5	705 c	7.28 cd
triadimefon	125	115	282	1.75	685 c	7.28 cd
vinclozolin	500	107	115	1.25	472 a	5.73 ab
benodanil	1000	111	114	0	565 ab	6.19 ab

1: sprayed 06.12.83, GS 23-24: 2: + wetter at 175 g a.i./ha

Table 4: Control of snow rot in Farmer Usage Trials

Location	Variety Spray date	g a.i./ha benodanil	Sclerotia	% Plants infected	Overall autumn fungicide
Auchterless	Irgi	Nil	546	42	triadimenol SD,
Grampian	1.12.83	500	98	12	prochloraz +
		1000	66	6	carbendazim+maneb
Rothienorman	Igri	Nil	160	12	T+C+M
Grampian	23.11.83	1000	0	0	
Tarland	Igri	Nil	880	60	(T+C+M) +
Grampian	25.10.83	1000	66	4	fenpropimorph
Tarland	Pirate	Nil	434	36	T+C+M
Grampian	25.10.83	1000	0	0	
Sherborne	Igri	Nil	1162	32	tridemorph
Gloucs	29.11.83	500	10	2	
		1000	0	0	
Tarves	Igri	Nil	980	56	triadimenol SD,
Grampian	17.11.83	1000	0	0	triadimefon,
					tridemorph +
					propiconazole +
					carbendazim+maneb

SD = seed dressing

DISCUSSION

The results presented demonstrate the ability of benodanil to consistently give excellent control of snow rot as measured by reductions in sclerotia production. Under severe infection conditions, benodanil has also led to correlated substantial increases in green tissue levels in the absence of other disease. The precise relationship between snow rot infection and yield loss has not yet been established, although it is clear that the disease can be devastating given suitable conditions. Further work is required to establish the level of infection at which control becomes economic. However, the value of such information must be limited in practice since the decision to treat or not must be made before the onset of winter conditions, which themselves largely determine the severity of infection.

As with other diseases, treatment criteria should also take account of the likely sources of infection. Although it is known that grasses may carry infection it has been suggested that the major source is via sclerotia in the soil (Lehmann, 1965 b). The reported results indicate that the benefits of benodanil may be realised in successive crops as well as the crop treated, since very few sclerotia are on average returned to the soil. The prospect of reducing sclerotia numbers even in regions of intensive winter barley production therefore exists. Triadimefon does not offer this possibility based on these results. Also in common with other diseases, the control of snow rot should be considered as part of the overall disease control strategy rather than in isolation,since it is known that snow rot infection interacts with crop conditon (Mathre, 1982). The results emphasise the benefit of broad spectrum fungicides.

BASF trials to date have not examined the timing of sprays to obtain optimum control of snow rot. Applications of benodanil in these trials have been made from late October to mid-January, and have never failed to give good control. An ADAS timing trial conducted in Oxfordshire comparing applications of benodanil and triadimefon from 18/11/83 to 17/1/84 also indicates that the timing is not critical (Dobson, 1984). Future BASF trials are planned to investigate the timing aspect, together with the possibilities for long-term control.

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RESPONSE OF EYESPOT ISOLATES TO MBC AND MDPC IN CULTURE AND IN POT EXPERIMENTS

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ABSTRACT

Twenty-one isolates of Pseudocercosporella herpotrichoides were tested for sensitivity to carbendazim (MBC) and methyl N-(3,5-dichlorophenyl)-carbamate (MDPC) in culture and eight were tested with wheat seedlings in pot experiments. In culture ten isolates sensitive to MBC were less sensitive to MDPC than were eleven isolates resistant to MBC. In pot experiments eyespot on wheat seedlings inoculated with MBC-sensitive isolates was controlled by weekly treatment with MBC (0.4-0.5 mg/pot) but not by MDPC (0.8-4 mg/pot). Eyespot on plants inoculated with MBC-resistant isolates and treated with MDPC was less severe than on plants treated with MBC, which had no effect.

INTRODUCTION

Over the past decade fungicides which generate methyl benzimidazol-2-yl carbamate (MBC) have been increasingly used to control eyespot, caused by Pseudocercosporella herpotrichoides, an important disease of winter cereal crops. One or more MBC (e.g. benomyl as Benlate or carbendazim as Bavistin) sprays were applied to 52% of winter wheat crops and 45% of winter barley crops surveyed in England and Wales in 1982 by the Agricultural Development and Advisory Service (ADAS) (Griffin & Yarham 1983). However, cases have recently been reported where MBC fungicides have failed to control eyespot, and MBC-resistant strains of P. herpotrichoides have been isolated from many of these crops. MBC-resistance was found in 23 out of 59 winter cereal crops from which P. herpotrichoides was isolated in the 1982 ADAS survey (Griffin & Yarham 1983).

On potato dextrose agar (PDA), P. herpotrichoides isolates which infect only wheat and barley (wheat-type) produce circular colonies with regular, even edges and grow at about twice the rate of isolates which infect wheat, barley and rye (rye-type) and produce irregular colonies with feathery edges (Scott et al. 1975). Both Griffin and Yarham (1983) and Brown et al. (1984) found a higher proportion of rye-type isolates (classification based on cultural characteristics) amongst the MBC-resistant isolates than amongst the MBC-sensitive isolates. In growth cabinets MBC-resistant isolates were as pathogenic to wheat seedlings as MBC-sensitive isolates (Brown et al. 1984).

Field isolates of Botrytis cinerea, Fusarium nivale, Mycosphaerella melonis, Venturia nashicola and Cercospora beticola have shown negatively correlated cross-resistance to MBC and phenyl carbamates in culture and in pot experiments (Leroux & Gredt 1982; Kato et al. 1983). This paper describes culture and pot experiments to test the activity of methyl N-(3,5-dichlorophenyl)-carbamate (MDPC) against MBC-sensitive and MBC-resistant isolates of P. herpotrichoides.

MATERIALS AND METHODS

Isolates

Fourteen isolates of *P. herpotrichoides* were from the Rothamsted farms at Harpenden and Woburn (isolates prefixed BK, BY or W), five were from UK commercial farms (prefixed C, D or S) and two were from West Germany. On the basis of cultural characteristics (Scott *et al.* 1975), eight isolates were classified as rye-type and thirteen as wheat-type.

Culture experiments

Isolates were tested for sensitivity to MBC and MDPC in groups of four or five; isolate BK28 was included in each test as a standard. Mycelial plugs (4 mm diameter) of *P. herpotrichoides* growing on one fifth concentration PDA were inoculated on to PDA plates containing MBC or MDPC or with no added fungicide. Fungicides were dissolved in methanol and from each solution 1 ml was added to 99 ml of sterilized, molten PDA. After mixing, the PDA was poured into Petri plates. Solutions were made up so that test plates contained 0.2, 0.5, 2, 20 or 100 µg/ml of MDPC or *c.* five concentrations of MBC between 0.02 and 1000 ug/ml; concentrations in the range 0.02-10 µg/ml were used for MBC-sensitive isolates and concentrations in the range 5-1000 µg/ml for MBC-resistant isolates. Methanol without fungicide was added to the fungicide-free plates. Three plugs of each isolate were placed on each of three replicate plates. Colony growth (diameter minus 4 mm) was measured after two weeks at 20°C. Fungicide concentrations required to inhibit colony growth by 50% (EC_{50}) were determined.

Pot experiments

In three randomised block experiments wheat seedlings were inoculated with wheat-type MBC-sensitive, wheat-type MBC-resistant, rye-type MBC-sensitive and rye-type MBC-resistant isolates. Three (experiment 1) or five replicate pots were used.

Isolates were grown for 3-4 weeks in potato dextrose broth on a shaking incubator. 20 ml samples from each homogenized broth culture were each mixed with 40 ml molten water agar, poured into Petri plates and incubated for 2 days at 20°C. Ten-day-old wheat plants (cv. Armada) growing in peat compost in 13 cm diameter pots (*c.* ten plants per pot) were inoculated by placing a collar (external diameter 10 mm, internal diameter 3 mm), cut from a water agar culture, round each coleoptile at soil level. Inoculum was covered with silver sand which was kept moist by daily watering. The plants were kept in a growth room with a 10 h day and 15°C day/10°C night temperatures.

In experiment 1 pots were treated with MBC (0.4 mg/pot) or MDPC (0.8 mg/pot); in experiments 2 and 3 they were treated with MBC (0.5 mg/pot), MDPC (1,2 or 4 mg/pot) or MBC (0.5 mg/pot) plus MDPC (2 mg/pot). MBC (as Bavistin) and MDPC were each dissolved or suspended at appropriate concentrations in methanol and from each solution 2 ml was added to 400 ml of 0.01% Tween 80 solution in water. Plants were treated weekly by adding 20 ml of fungicide solution to each pot. Untreated plants received Tween 80 solution only.

After six weeks eyespot severity was scored according to the number of leaf sheaths infected or penetrated (Scott 1971) and mean penetration indices per pot were calculated.

RESULTS

Of the twenty-one P. herpotrichoides isolates tested in culture (Table 1), ten were MBC-sensitive (EC_{50} 0.02-0.08 µg/ml) and eleven were MBC-resistant (EC_{50} > 50 µg/ml). The MBC-sensitive isolates had greater EC_{50}s for MDPC (10-100 µg/ml) than did MBC-resistant isolates (0.5-2 µg/ml). Eight wheat-type isolates were MBC-sensitive and five were MBC-resistant, and two rye-type isolates were MBC-sensitive and six were MBC-resistant.

TABLE 1

Growth of P. herpotrichoides isolates on potato dextrose agar containing MBC or MDPC.

Isolate Code	Growth type*	MBC EC_{50}(µg/ml)		MDPC EC_{50}(µg/ml)	
		0.02-0.08	>50	0.5-2	10-100
BK28	W	+			+
BK45	R	+			+
BK51	W	+			+
BK57	W	+			+
BK91	R		+	+	
BY2	W		+	+	
BY149	W		+	+	
BY151	W		+	+	
BY177	W	+			+
BY212	W	+			+
W100	W	+			+
W108	W	+			+
W125	R		+	+	
W127	R		+	+	
C20	R		+	+	
D12	W		+	+	
D21	R		+	+	
D39	R		+	+	
S11	W		+	+	
987	W	+			+
998	R	+			+

* W: wheat-type; R: rye-type

EC_{50}: fungicide concentration required to inhibit growth by 50%

In three pot experiments wheat seedlings inoculated with MBC-sensitive P. herpotrichoides isolates (wheat-type or rye-type) developed significantly ($P<0.001$) less eyespot when treated weekly with MBC (0.4 or 0.5 mg/pot) than when untreated (Table 2). However, treatment with MBC did not affect the severity of eyespot symptoms caused by MBC-resistant P. herpotrichoides isolates (wheat-type or rye-type).

There was a significant ($P<0.05$) treatment by isolate interaction in all three experiments; treatment with MDPC (1 mg/pot) decreased the severity of eyespot symptoms on wheat seedlings inoculated with MBC-resistant isolates, significantly ($P<0.01$) in experiments 2 and 3, but did not affect eyespot caused by MBC-sensitive P. herpotrichoides. Increasing the dosage of MDPC to 2 or 4 mg/pot did not improve the control of eyespot caused by MBC-resistant isolates , which was less effective than the control achieved by MBC treatment of eyespot caused by MBC-sensitive isolates. In experiment 2, but not in experiment 3, significantly ($P<0.05$) less eyespot developed on seedlings inoculated with MBC-resistant isolates and treated weekly with a combination of MBC and MDPC than on similar seedlings treated with MDPC alone.

DISCUSSION

In these experiments P. herpotrichoides showed a negatively correlated cross-resistance to MBC and MDPC both in culture (Table 1) and on wheat seedlings in pots (Table 2). In this respect it is similar to other fungi which show this negative cross-resistance (Leroux & Gredt 1982; Kato et al. 1983); the mechanism of MBC-resistance may be the same.

These results suggest that MDPC may be useful for the control of MBC-resistant eyespot. However, the effect of MDPC on MBC-resistant isolates of P. herpotrichoides was less than that of MBC on MBC-sensitive isolates both in culture (Table 1) and on wheat seedlings in pots (Table 2). Further experiments are needed to determine what amounts of MDPC were reaching the eyespot lesions on pot-grown plants, to investigate whether the plant was modifying the effect of the chemical and to test the effect of MDPC on infected wheat crops. The slight enhancement of the effect of MDPC on MBC-resistant eyespot by the addition of MBC (Table 2) also merits further investigation. The negative cross-resistance of P. herpotrichoides to MBC and MDPC may be better exploited using other compounds analagous to MDPC but more effective as fungicides.

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TABLE 2

Effects of MBC and MDPC on growth of MBC-sensitive (S) and MBC-resistant (R) isolates of <u>P. herpotrichoides</u> in wheat.

Treatment	Eyespot penetration index			
	Isolate			
	Wheat-type (S)	Wheat-type (R)	Rye-type (S)	Rye-type (R)
Experiment 1	BK51	D12	BK45	W125
Untreated	3.20	4.86	3.58	4.23
MBC (0.4 mg/pot)	1.18**	4.15	0.10***	4.23
MDPC (0.8 mg/pot)	3.69	3.63	3.56	2.96
SED (22 d.f.) 0.68				
Experiment 2	BK57	D12	BK45	
Untreated	5.58	6.14	4.18	
MBC (0.5 mg/pot)	0.12***	6.01	0.13***	
MDPC (1 mg/pot)	5.93	5.18**	3.96	
MDPC (2 mg/pot)	5.95	5.06***	3.93	
MDPC (4 mg/pot)	5.70	5.34**	3.80	
MBC (0.5) + MDPC (2 mg)	0.49***	4.41***	0.87***	
SED (68 d.f.) 0.30				
Experiment 3		BY151	998	BK91
Untreated		4.95	4.45	4.21
MBC (0.5 mg/pot)		4.89	0.12***	4.24
MDPC (1 mg/pot)		1.59***	4.81	2.55***
MDPC (2 mg/pot)		1.08***	5.00	1.86***
MDPC (4 mg/pot)		1.33***	4.81	1.96***
MBC (0.5 mg + MDPC (2 mg)		0.73***	0.20***	1.84***
SED (68 d.f.) 0.37				

Significant differences from untreated: **($P<0.01$), ***($P<0.001$)

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THE EFFECT OF BROWN RUST ON YIELD OF WINTER WHEAT

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ABSTRACT

Two trials in 1983 provided data on control of brown rust (Puccinia recondita) of winter wheat, and on the effect of the disease on crop yield. Fenpropimorph, propiconazole and triadimefon were the most effective fungicides for brown rust control, and gave yield increases of up to 2.20 t/ha. The relationship between brown rust and yield was that each 1% increase in disease on the flag leaves at the milky-ripe stage (GS 73) was associated with yield losses of 0.82% in one trial and 0.84% in the other.

INTRODUCTION

Brown rust (Puccinia recondita) of winter wheat frequently affects susceptible cultivars in Southern England. The disease can sometimes be detected early in the year, but rapid development usually occurs in late June or early July. There is no published data from the UK on the effect of brown rust on yield of winter wheat.

This paper reports the results of 2 trials in 1983 which provided data on the relationship between brown rust severity and yield loss. Trial 1 was a comparison of fungicide programmes, in which brown rust was the major disease, whereas in Trial 2 the treatments were designed to give differing severities of brown rust.

MATERIALS AND METHODS

Both trials were marked out in commercial crops of winter wheat. Trial 1 was in a field of cv. Avalon near Blandford Forum, Dorset, and Trial 2 was in cv. Armada near Canterbury, Kent. Both cultivars are highly susceptible to brown rust (NIAB, 1984). The layout for each was a randomised block with 4 replicates, and the plot size was $60m^2$. Fungicides were applied at manufacturers' recommended rates (Table 1) on the dates given in Tables 2 and 3, in 200 litre (Trial 2) or 250 litre (Trial 1) of water per hectare using a knapsack sprayer. Growth stages were assessed according to the decimal growth stage key of Zadoks et al (1974). The trials were harvested using a farm combine harvester.

RESULTS

Brown rust assessments and yield responses are given in Tables 2 and 3.

In Trial 1 (Table 2), brown rust was not detected until mid-June, but disease levels increased rapidly in late June and early July. Levels of other diseases were very low. All treatments which included a spray at

GS 41 or sprays at GS 39 and GS 59 gave a significant reduction ($p<0.05$) in brown rust on the flag leaves, with the exception of prochloraz at GS 41. The most effective programmes for control of brown rust were those including fenpropimorph, propiconazole or triadimefon. The greatest yield increases, up to 2.20 t/ha were given by the 3-spray programmes, and the 2-spray programmes which included fenpropimorph.

In Trial 2 (Table 3) brown rust was found in the trial in late January but levels did not increase appreciably until late June. All fungicide treatments gave good control of brown rust at GS 73 but disease severity had increased by GS 81, particularly in the treatments which had not been sprayed since GS 39. All fungicide treatments gave significant yield increases ($p<0.05$). The yield increases from the 4-spray programmes, which included a spray at GS 65 (1.46-2.01 t/ha), were greater than those from the 3-spray programmes in which the last spray was at GS 39 (1.02-1.08 t/ha) ($p<0.05$).

Regressions of % brown rust on the flag leaf at GS 73 on yield, calculated from individual plot data, are given in Table 4. The regressions for Trial 1 and Trial 2 were not significantly different.

DISCUSSION

Brown rust did not develop at either site until late June, so it is unlikely that fungicides applied before GS 39 would have had much, if any, effect on disease development. The control of brown rust can therefore be attributed to the fungicides applied at GS 39 or later. The efficacy of fenpropimorph, propiconazole and triadimefon for control of brown rust was demonstrated; this confirms earlier reports (Rowley et al, 1977; Smith and Speich, 1981; Atkin et al, 1981). Differences between these 3 fungicides in rust control were small and not statistically significant. Control of rust gave substantial, significant ($p<0.05$) and cost-effective yield increases in both trials. In Trial 2, the treatments which included a spray at GS 65 gave better control of rust and significantly higher yields ($p<0.05$) than those in which the last spray was at GS 39. However, these trials do not provide information on the effectiveness of a single spray at ear emergence or anthesis (GS 59-69) in the absence of earlier sprays.

The regressions show that the effects of brown rust on yield were similar at the 2 sites, with each 1% increase in disease on the flag leaf associated with yield loss of 0.82% in Trial 1 and 0.84% in Trial 2. There is no other data from the UK on winter wheat, but these figures are comparable with estimates of yield loss of barley due to brown rust (Puccinia hordei). On winter barley Udeogalanya and Clifford (1982) estimated yield losses of 0.6-1.5% for each 1% increment of brown rust on whole plants at GS 75. On spring barley, Melville et al (1976) estimated a yield loss of 0.77% for each 1% brown rust on leaf 2 at GS 75, although King and Polley (1976) estimated that yield losses were lower, at 0.6% and 0.4% for each 1% brown rust on leaves 1 and 2 respectively at GS 75.

Burleigh et al (1972) published a formula for estimating the yield loss of winter wheat from assessments of brown rust severity at 3 growth stages.

Yield loss = $5.3788 + 5.526\ x_2 - 0.3308\ x_5 - 0.5019\ x_7$

where x_2 = severity of rust on the whole tiller at GS 45-49
x_5 = severity of rust on the flag leaf at GS 71
x_7 = severity of rust on the flag leaf at GS 79-81

Severity was measured as percentage leaf area affected.

Assessments of brown rust were made on Trial 2 at GS 49, GS 73 and GS 81 and for each treatment the predicted yield loss was calculated using this formula. The difference between the mean predicted yield loss and mean actual yield loss for the 7 treatments was 2.1%, so the formula provided a good estimate of yield losses in Trial 2. However, the regressions from the 2 trials reported in this paper, based on single assessments at GS 73, were in close agreement, and were not significantly different. It is possible that yield losses caused by brown rust can be estimated with the same degree of precision from a single disease assessment at GS 73 as from a series of assessments.

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TABLE 1

Fungicides used, and rate(s) of a.i. per hectare

Fungicide	Product(s) (trade names)	Formulation	Application rate of a.i. per ha
benomyl	Benlate	50% w.p.	0.25 kg
carbendazim	Battal	50% flowable	0.25 l
carbendazim	Bavistin	50% w.p.	0.25 kg
carbendazim	Derosal	50% flowable	0.25 l
carbendazim + "activator"	Supercarb	25% w.p.	0.25 kg
carbendazim + maneb	Delsene M	10% + 64% w.p.	0.25 + 1.6 kg
carbendazim + maneb + sulphur	Bolda	8% + 53% + 17% w.p.	0.24 + 1.59 + 0.51 kg
chlorothalonil	Bravo 500	50% flowable	1.0. l
fenpropimorph	Corbel	75% e.c.	0.75 l
fenpropimorph	Mistral	75% e.c.	0.75 l
iprodione	Rovral Flo	25% flowable	0.5 l
mancozeb + maneb	Kascade	40% + 40% w.p.	0.8 + 0.8 kg
prochloraz	Sportak	40% e.c.	0.4 l
prochloraz+ carbendazim	Sportaz alpha	26.7% + 10% e.c.	0.4 + 0.15 l
propiconazole	Tilt	25% e.c.	0.125 or 0.25 l
propiconazole + carbendazim	Hispor	25% + 20% w.p.	0.125 + 0.1 kg
pyrazophos	Missile	30% e.c.	0.6 l
pyrazophos + captafol	HOE 733	17% + 33% w.p.	0.51 + 1.0 kg
sulphur	Thiovit	80% w.p.	8.0 kg
triadimefon	Bayleton	25% w.p.	0.125 kg
triadimefon + captafol	Bayleton CF	6.25% + 65% w.p.	0.125 + 1.3 kg
triadimefon + carbendazim	Bayleton BM	12.5% + 25% w.p.	0.125 + 0.25 kg
triforine + carbendazim	Brolly	10% + 10% flowable	0.2 + 0.2 l

TABLE 2

Brown rust control and yield, Trial 1 (Dorset)

Treatments: GS 31 (14 April)	Treatments: GS 41 (24 May)	% brown rust leaf 1 GS 73	Yield (t/ha at 85% d.m.)
untreated	untreated	29.1 t	7.03 f
carbendazim[1] + triadimefon + captafol	carbendazim[1] + triadimefon + captafol*	11.1zyxw	9.23a
carbendazim[1]	untreated	32.5 t	7.13 f
untreated	triadimefon + captafol	13.7zyxwv	8.22 bcde
carbendazim[1]	triadimefon + captafol	16.5 yxwv	8.30 bcd
triadimefon + carbendazim	triadimefon + captafol	11.9zyxw	8.48abc
carbendazim[1] + fenpropimorph[4]	carbendazim[1] + fenpropimorph[4] + chlorothalonil	10.1zyxw	9.00ab
prochloraz + carbendazim	prochloraz	26.6 ut	7.59 cef
propiconazole + carbendazim	propiconazole (0.25 l/ha a.i.)	10.6zyxw	8.49abc
propiconazole + carbendazim	propiconazole* (0.125 l/ha a.i.)	5.9z	8.96ab
benomyl	carbendazim + maneb	17.3 xwv	7.67 def
propiconazole + carbendazim	propiconazole (0.125 l/ha a.i.)	9.6zyx	8.45ab
carbendazim[3] + pyrazophos	pyrazophos + captafol	20.8 vu	8.48abc
carbendazim + "activator" + sulphur	maneb + mancozeb + carbendazim + triforine	20.4 vu	7.48 ef
carbendazim[2]	carbendazim + maneb + sulphur	18.2 wv	7.72 cdef
thiophanate-methyl + fenpropimorph[5]	thiophanate-methyl + iprodione + fenpropimorph[5]	8.6zy	8.97ab
cv (%)		30.1	6.06
S.E.D. ($p < 0.05$)		3.49	0.35

Means followed by a common suffix letter do not differ significantly ($p < 0.05$) (Duncan's multiple range test.)

*Fungicides applied at GS 39 (19 May) and GS 59 (9 June), not GS 41.

carbendazim products were: 1 - Bavistin; 2 - Battal; 3 - Derosal.
fenpropimorph products were: 4 - Corbel; 5 - Mistral.

TABLE 3

Brown rust control and yield, Trial 2 (Kent)

Treatments	% brown rust on leaf 1 GS 73	% brown rust on leaf 1 GS 81	Yield (t/ha at 85% d.m.)
untreated	20.5 v	45.3 d	8.19 d
propiconazole[1] at GS 23, 31, 39 and 65	1.4zyx	8.7ab	9.65 b
triadimefon at GS 23, 31, 39 and 65	1.5zyxw	8.9ab	9.69 b
fenpropimorph[2] at GS 23, 31, 39 and 65	0.4z	5.7a	10.20a
propiconazole at GS 23, triadimefon at GS 31 and fenpropimorph at GS 39	3.1 yxw	21.7 bc	9.27 c
triadimefon at GS 23, fenpropimorph at GS 31 and propiconazole at GS 39	3.9 xw	29.1 cd	9.21 c
fenpropimorph at GS 23, propiconazole at GS 31 and triadimefon at GS 39	4.7 w	30.8 cd	9.23 c
cv (%)	24.0	15.6	2.46
S.E.D. ($p<0.05$)	1.87	2.87	0.17

Means followed by a common suffix letter do not differ significantly ($p < 0.05$) (Duncan's multiple range test.)

Dates of spray application:

GS 23	4 April
GS 31	22 April
GS 39	25 May
GS 65	16 June

1 : propiconazole was applied at 0.125 1 a.i./ha
2 : the fenpropimorph product used was Corbel

TABLE 4

Regression of % brown rust infection of flag leaf at GS 73 on yield

Trial	Regression	S.E. of regression	Correlation coefficient	% variance accounted for	% yield loss for each 1% increase in disease
1	$Y = 9.48-0.078x$	0.012	- 0.88	76.0	0.82
2	$Y = 9.76-0.082x$	0.015	- 0.91	80.9	0.84

CHEMICAL CONTROL OF WHEAT RUSTS OCCURING IN GREECE

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ABSTRACT

Effective control of leaf and stem rust have been obtained in field trials from a single application of benodanil, diclobutrazol, nuarimol, oxycarboxin, propiconazole, sisthane and triadimefon, while less satisfactory with pyracarbolid. Drazoxolon and Indar (4-n-butyl - 4H-1,2,4-triazole) gave effective control of leaf rust and EL2871 (nuarimol 6% + chlorothalonil 60%), fenpropimorph, tridemorph and triforine of stem rust. Statistically significant yield increases over untreated plots were obtained in nine from 11 trials after sprays with effective fungicides. In some trials yield increases were high in others smaller, depending on the disease severity, as well as rate and stage at application of the chemicals. In glasshouse tests oxycaboxin and HOE 13764 (BCM 10% + pyracarbolid 10%) were effective as curative fungicides against wheat leaf and stem rusts the first and leaf rust the second. However, benlate and Indar were better protectants.

INTRODUCTION

Wheat leaf rust (*Puccinia recondita*) is present every year in large cereal growing areas of Greece and causes some losses, which are considered as rather unimportant, because the disease is not totally destructive. However, chemical control of this disease resulted in yield increases more than 30%.

Stem rust (*Puccinia graminis*) is not found every year over such large areas as leaf rust, but it is more destructive, causing some years more than 60% yield loss with susceptible varieties. Although the gradual substitution of the susceptible varieties to rusts by resistant or tolerant have reduced the losses, the frequent appearence of new races requires very often the chemical control of these diseases. An ideal method of controlling wheat rust would be the single application of a persistent and curative systemic fungicide, for most cost effective use of fungicides. The introduction of broad spectrum fungicides, which offered good control of powdery mildew (*Erysiphe graminis*) and rusts, further encouraged fungicide use (Bent & Skidmore 1979, Smith & Speich 1981).

In a series of experiments under glasshouse and field conditions we attempted to study the effectiveness of 28 fungicides or mixtures against wheat leaf and stem rusts in Greece.

METHODS AND MATERIALS

a. Glasshouse spray tests Tests were done on potted wheat plants, cv Aeges, Michingan Amber, G38290, Niki and Kota. Commercial formulations of fungicides were applied at manufacturers recommended or lower spray concentrations for field applications at 250 l/ha. Materials were sprayed to maximum retention to 7 or 12 day old seedlings with one fully expanded leaf.

Ten pots of wheat seedlings for each variety and treatment were inoculated with an uredial suspension of mixed leaf or stem rust races and incubated in large polyethylene frames in a glasshouse. Plants in these pots were sprayed with fungicides 2 or 5 days after inoculation.

Diseases were assessed on all plants 14 days after inoculation by estimating the type of infection (scale 0-4, 0 = no infection 4 = very susceptible with large uredia).

b. Field experiments All trials were based on six replicate plots with a randomized block design and with borders of a mixture of wheat varieties susceptible to stem or leaf rust. The borders of the five experiments were inoculated artificially with an uredial mixture of the prevalent leaf rust races in Greece and the other six with a mixture of stem rust prevalent races.Therefore in the five experiments was developed only leaf rust,whereas in the other six only stem rust. The plots (15-30 m^2) were sprayed with an Azo propane knapsack precision sprayer with cone nozzles. Assessments were made according to the modifield Cobb's scale.

List of fungicides used

Fungicide	Supplier	Fungicide	Supplier
Benomyl	Du pont	Benodanil	BASF
Carbendazim	BASF	Benodanil+tridemorph (BAS4040)	"
Ditalimfos	Dow	Diclobutrazol	ICI
Drazoxolon	ICI	Diclobutrazol+captafol or BCM	"
Fenpropimorph	BASF	Indar	Rohn & Haas
Imazalil	Janssen	Indar+mancozeb	" "
Iprodione	Phone Poulenc	Nuarimol	Eli Lilly
Mancozeb	Rohn & Haas	Nuarimol+chlorothalonil (EL2871)	" "
Prochloraz	FBC	Oxycarboxin	Uniroyal
Sisthane	Rohn & Haas	Oxycarboxin+methyl thiophanate	"
Thiabendazole	Merk Sharp	Propiconazole	Ciba-Geigy
Triadimefon	Bayer	Propiconazole + captafol	" "
Tridemorph	BASF	Pyracarbolid	Hoechst
Triforine	Celamerck	Pyracarbolid+BCM (HOE 13764)	"

RESULTS

a. Glasshouse tests

(i) Leaf rust Benomyl, Indar, HOE 13764 and oxycarboxin,when applied 2 days after inoculation with leaf rust almost completely prevented disease development (Table 1). Benomyl and Indar provided a high degree of rust control even where their application was delayed five days, while oxycarboxin and HOE 13764 gave complete control of leaf rust in this case.

(ii) Stem rust Oxycarboxin provided complete control of wheat stem rust at the two rates of application regardless of time of application after inoculation. Benomyl provided also complete control of the disease at both rates, when the chemical was applied 2 days after the inoculation and some degree of stem rust control, when delayed five days after inoculation.

b. Field trials

In trial 1 the results show(Table 2) that the best disease control was obtained with the two rates of Indar or Indar + mancozeb, but neither material completely prevented the development of the disease until the end of the season. The other tested chemicals had no significant effect

TABLE 1

Effect of fungicide timing on leaf and stem rusts infection type in glasshouse

Treatments	Rate g a.i./ha	Application time (days after inoculation)									
		2	5	2	5	2	5	2	5	2	5
		Leaf rust				Stem rust					
		cv Mich. Amber		Aeges		G38290		Niki		Kota	
Benomyl	200					0	3	0	1	0	3
"	250	0	1	0	1	0	1	0	1	0	3
Oxycarboxin	400					0	0	0	0	0	0
"	500	0	0	0	0	0	0	0	0	0	0
Indar	2 000	0	2	0	1						
"	4 000	0	1	0	1						
HOE13764	400	0	0	0	0						
Untreated		4		3		4		2		4	

TABLE 2

Comparison of fungicides for control of leaf and stem rusts

Treatments	Rate g a.i./ha	Infection of leaf rust %		Yield % of control	Infection of stem rust %		Yield % of control
		Trial 1			Trial 2		
Oxycarboxin	500	31a*	73a	110bc	45c		129a
Carbendazim	250	37a	80a	109bc	52bc		136a
Imazalil	250	33a	80a	106cd	50bc		111bc
Pyracarbolid	600	-	-	-	48bc		123ab
Triforine	228	-	-	-	47bc		125ab
Indar	2 000	5b	17b	110bc			
"	4 000	5b	12b	116ab			
Indar + mancozeb	2 000 1 600	5b	17b	112bc			
Indar + mancozeb	4 000 1 600	5b	10b	124a			
Mancozeb	1 600	38a	80a	104cd			
Untreated		40a	80a	100d	67a		100c
		Trial 3			Trial 4		
Benodanil	300	35ab		101d	6d	17c	118ac
"	375	23c		114ac	8cd	20bc	115ac
Oxycarboxin wp	500	23c		118ab	8cd	21bc	119ab
" wp	600	18cd		121a	12bc	23bc	116ac
" ec	500	25c		115ac	10bc	22bc	121a
" ec	600	21c		111bc	8cd	21bc	115ac
Oxycarboxin + thiophanate methyl	250 250	-		-	8cd	22bc	117ac
Pyracarbolid	350	28ab		109bd	12d	32b	102d
"	500	25c		107cd	9bd	31b	106cd
"	600	20cd		111bc	6d	27b	107cd
Untreated		43a		100d	22a	47a	100d

* Values with a common letter suffix are not significant different at $p = 0.05$.

TABLE 2 (continue)

Treatments	Rate g a.i./ha	Infection of leaf rust %	Yield % of control	Infection of stem rust %		Yield % of control
			Trial 5			
Benodanid+sticker	450	10de	127ab			
"	450	12de	132a			
"	600	11de	130a			
Benodanil+ tridemorph	240 120	25c	113ce			
Drazoxolon	1 000	8e	137a			
Iprodione	400	30ac	105df			
Oxycarboxin	500	12de	126ac			
Untreated		40a	100ef			
			Trial 6		Trial 7	
Benodanil	750	22b	143a	26bc		113ab
Nuarimol	90	20b	149a	20c		118ac
Oxycarboxin	500	28b	108cd	27bc		116ac
Sisthane*	350	25b	119bc	18c		119a
"	700	22b	126b	23c		112ac
" **	350	27b	134ab	35b		110ac
"	700	25b	122bc	33b		111ac
Triadimefon	150	19b	144a	32b		110bc
"	250	20b	125bc	28bc		110bc
Benodanil	600			20c		116ac
Ditalimfos	500			35b		110ac
"	600			28bc		107cd
Untreated		47a	100d	50a		100d
			Trial 8		Trial 9	
Diclobutrazol	125	3c	104	13bc	30bd	124ab
"	250	0d	102	12c	22d	135a
Propiconazole	100	12b	103	17b	42ac	104de
"	125	10b	109	14bc	34bd	117bc
"	150	12b	112	13bc	33bd	109cd
"	200	9b	109	12c	28cd	111bd
"	250	11b	111	16bc	35bd	110cd
[Propiconazole+ captafol]	100+600	11b	105	17b	37bc	110cd
"	125+600	10b	106	15bc	32bd	110cd
"	150+600	9b	102	14bc	33bd	113bc
Triadimefon	125	-	-	17b	42ac	101ce
Untreated		22a	100	31a	54a	100de

* Spray at GS39
** Spray at GS50

on leaf rust. The disease control reflected in the yield data, where Indar + mancozeb gave a yield increase of over 20% compared to untreated plots.

In trial 3 plots treated with benodanil, oxycarboxin and pyracarbolid gave lower amount of leaf rust and more yield compared with the untreated plots or plots sprayed with the lower rates. The same fungicides tested for stem rust (trials 2 and 4) reduced the stem rust infection and produced yield increases. In the trial 2 oxycarboxin, carbendazim and triforine gave high yield increases (23-36%). Also in the trial 5 benodanil, drazoxolon and oxycarboxin controlled leaf rust satisfactorily and gave high yield increases (26-37%).

A single spray at two rates of sisthane applied at GS39 to GS50 (Trials 6 and 7) gave about the same control of leaf and stem rusts 73-78% and 65-82%, respectively, almost the same with benodanil, nuarimol, oxycarboxin and triadimefon and also increased yields.

In trial 8 treatments with diclobutrazol, propiconazole, propiconazole + captafol and triadimefon reduced the leaf rust infection but did not result in a significant yield increase compared to untreated plots, because of the relative low infection of the trial throughout the season (22MS). Propiconazole or propiconazole + captafol showed rather shallow dose-response relationship in disease. Mixtures of propiconazole plus captafol had to benefit over propiconazole alone. In trial 9 the same fungicides with those of trial 8 reduced the stem rust infection and produced yield increases some of which are not statistically significant.

TABLE 3

Comparison of fungicides for control of leaf and stem rusts

Treatments	Rate g a.i./ha	Stem rust %	Yield %	Treatments	Rate g a.i./ha	Stem rust %	Yield %
		Trial 10				Trial 11	
Diclobutrazol	125	14bc	101ce	Fenpropimorph	375	36b	114
Diclobutrazol +	125	7c	103ce	"	750	28c	108
captafol	600			"	1 125	20d	108
Diclobutrazol +	125	8c	98ce	Prochloraz	200	42a	108
carbendazim	200			"	400	29c	99
EL2871	132	13c	130a	"	600	33bc	112
"	198	8c	122ab	Thiabendazole	300	27c	105
"	264	11c	114ac	Triadimefon	125	23cd	115
Propiconazole	125	12c	101ce	Tridemorph	525	20d	108
"	200	12c	103ce	Untreated	-	48a	100
Propiconazole+	125	7c	108be				
captafol	400						
Triadimefon	125	25b	113bd				
Untreated		37a	100ce				

In trial 10 treated plots with diclobutrazol alone and with captafol or carbendazime, EL 2871 and propiconazole alone and with captafol reduced levels of stem rust through May, although these differences did not persist into the end of the season. The increase of yield was only significant with EL 2871 applications (table 2).

In another trial (11) single spray of fenpropimorph and prochloraz at three rates, thiabendazole, triadimefon and tridemorph reduced levels of stem rust through May, but these differences did not persist into the end of season. There was no significant difference in yields between treatments due to relatively late infection.

DISCUSSION

The results compiled from 11 trials in Greece show that most of the fungicides applied at different rates and growth stages provide control of both leaf and stem rusts or only one of the two. This control has been obtained under a variety of conditions, including those in which infection of rusts are considered to be a serious problem. Therefore there was a marked variation between trials in the response to the fungicides tested.

It is worth noting that percentage control of disease symptoms with most fungicides was only 70-85% falling to 0-10% at the end of the season but with some exceptions. This level of control would not be considered satisfactory, but is the best that can be achieved in trials, where high amounts of inoculum existed up to the end of the season from the artificially infected borders, control plots or plots sprayed with ineffective fungicides. Also it is worth noting that the majority of data reports on treatments made after the first symptoms of the diseases were visible, because such treatments may be the usual practice in Greece and in other countries. Moreover if infection pressure is allowed to build up within the trial from early stage, because of favorable conditions, a considerable proportion of wheat plants may be infected before treatment is applied, although typical disease symptoms may not be evident. There are also some data which indicated that application of the same chemicals made before the appearence of these diseases gave better control than after it. Greenhouse tests have confirmed the more effective control of both rusts by an application of fungicides made prior to infection.

Statistically significant yield increases over untreated plots were obtained in nine trials, from the 11, after sprays with effective fungicides. In some trials yield increases were high, in others smaller, depending on the disease severity, as well as rate and stage of application of the chemicals. However, in some trials, where infections of rusts were not so serious, control of them by chemicals has effectively extended the life of the plants and resulted in some yield increases. The same was true with carbendazim or some other fungicides of which application gave increase of yield without controlling the disease. MBC-generating compounds are known to give a "tonic" effect on crops resulting in consistent improvements in yield (Allison et al., 1975).

In general, from this work it is clear that the use of effective fungicides against both rusts will result in high yield increase in places, where rust is a serious problem.

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COMPARISON OF SOME ASPECTS OF MILDEW FUNGICIDE USE ON SPRING BARLEY IN SOUTH-EAST SCOTLAND IN 1982 AND 1983

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ABSTRACT

Golden Promise, which is extremely susceptible to mildew (*Erysiphe graminis*), occupied 75% of the spring barley area in both years. The extent of mildew seed treatment and spray fungicide usage was very similar in both years, but less Golden Promise was sprayed twice in 1983. All seed treatments and sprays gave better control of mildew in 1983 than in 1982. On Golden Promise without mildew seed treatment, triadimefon and propiconazole constituted 55% of first sprays in 1982, but only 9% in 1983, while fenpropimorph and tridemorph accounted for 70% of both first and second sprays in 1983. Overall, 12% of second sprays in 1983 were fungicide mixtures, usually including tridemorph.

INTRODUCTION

Changes in the relative performance of different groups of fungicides in controlling mildew on spring barley in south-east Scotland were observed between 1980 and 1982 (Gilmour 1983). A postal survey of spring barley growers showed clearly that mildew control problems with some fungicides were widespread in 1982 (Gilmour 1984). The generally dry conditions favourable for mildew development, changes in the sensitivity of the mildew population towards the widely used triazole group of fungicides, and delay in applying the first sprays until after mildew was well established, may all have contributed to the problem.

To avoid similar problems in 1983, spring barley growers were advised, *inter alia*, to reconsider their commitment to the highly susceptible cultivar Golden Promise; to use two-treatment programmes on susceptible cultivars, either a mildew seed treatment followed by a spray, or a two-spray programme; to use mildew seed treatments where there was a risk of early infection; to use chemically different fungicides for follow-up treatments; to spray Golden Promise without mildew seed treatment while the disease was at very low levels (Gilmour 1982). This paper reports some of the results of a postal survey carried out in 1983 in comparison with those obtained from the 1982 survey.

MATERIALS AND METHODS

A questionnaire was sent to all cereal growers in south-east Scotland at the beginning of July in 1982 and 1983. Spring barley growers were asked to provide, anonymously, information about the mildew fungicides they had used, separately for each variety and each combination of fungicides. In 1982 replies were received from 950 farms growing 69,937 hectares of spring barley and gave information on 2,221 combinations of cultivar and fungicide programme. In 1983, 687 replies were received, covering 46,119 hectares of spring barley in 1,446 combinations of cultivar and fungicide programme.

All the data are presented as "percentage area" and the "survey area" stated in hectares. Corresponding survey areas may differ from table to table because units are excluded when essential classification factors are missing. All table entries have been rounded to the nearest 1 per cent: those within parentheses are based on small survey areas. Entries have been omitted (-) where the survey area was considered too small to allow valid comparison. The data were tabulated using the GENSTAT statistical package on the EMAS 2972 computers of The Edinburgh Regional Computing Centre and the VAX-11/750 computer of The Edinburgh School of Agriculture.

RESULTS

The overall proportion of the spring barley treated with mildew fungicides was very similar in both years, but 10 per cent less of the crop was sprayed twice in 1983 (Table 1).

TABLE 1
Proportion of spring barley treated with mildew fungicides (percentage area over all cultivars and treatments)

Year	Seed treatment	Sprayed at least once	Sprayed at least twice	Sprayed three times
1982	36	95	39	2
1983	39	94	29	1
Survey area (ha) 1982	68,970	69,348	68,770	69,586
Survey area (ha) 1983	45,929	45,729	45,822	45,614

Cultivar popularity was remarkably similar in the two seasons overall and within Regions (Table 2), but in the Border Region half of the Midas was replaced by a range of other cultivars in 1983. In neither year did any cultivar other than Golden Promise, Midas or Triumph account for more than 3 per cent of the overall area. In 1982 cultivar mixtures were grown on 0.3 per cent of the surveyed area: none was recorded in the 1983 survey.

TABLE 2
Cultivar popularity (percentage area overall and within Regions)

Cultivar	Overall 82	Overall 83	Border 82	Border 83	Lothian 82	Lothian 83	Fife 82	Fife 83	Tayside 82	Tayside 83
Golden Promise	76	75	58	56	68	73	79	79	89	83
Midas	7	5	14	7	10	7	7	5	2	3
Triumph	6	7	9	8	7	5	7	9	4	7
Others [21 & 19]	11	13	19	29	15	14	8	7	5	8
Survey area (ha) 1982	68,345		15,285		8,962		12,919		24,128	
Survey area (ha) 1983	44,393		7,563		6,573		8,741		15,062	

As Golden Promise predominated, most of the information given here is restricted to this cultivar. Mildew seed treatments were used on almost half of the surveyed Golden Promise in both years, and most of it was sprayed at least once (Table 3). In 1983 less of the Golden Promise without mildew seed treatment was sprayed twice. In both years seed treatment reduced the need for a second spray.

TABLE 3
Golden Promise mildew seed treatments and proportion of each sprayed once or twice (percentage area)

Seed treatment	Overall 82	Overall 83	Within seed treatment: sprayed once 82	sprayed once 83	sprayed twice 82	sprayed twice 83
Nil	56	52	100	100	61	50
ethirimol	24	29	97	99	28	26
triadimenol	9	14	94	93	9	10
triforine	7	3	99	100	50	6
thiophanate-methyl	3	1	100	-	53	-
nuarimol	$<\frac{1}{2}$	$<\frac{1}{2}$	-	-		-
Survey area (ha) 1982	51,115		50,876		50,199	
Survey area (ha) 1983	33,242		33,051		32,945	

Growers' ratings of the mildew control (in five subjective categories) given by the three main seed treatments were very similar in 1982 (Table 4). All seed treatments were given better ratings in 1983.

TABLE 4
Growers' mildew control ratings for seed treatments on Golden Promise (percentage area within seed treatment)

Mildew control	ethirimol 82	ethirimol 83	triadimenol 82	triadimenol 83	triforine 82	triforine 83
Excellent	7	13	11	29	15	21
Good	27	44	29	41	20	37
Satisfactory	38	31	39	26	40	36
Poor	25	9	19	3	21	6
Very poor	4	3	2	0	3	0
Survey area (ha) 1982	12,136		4,665		3,394	
Survey area (ha) 1983	9,313		4,542		976	

TABLE 5
Time of first mildew spray on Golden Promise relative to herbicide application (percentage area of seed treatment sprayed)

Time of first spray	No seed treatment 82	No seed treatment 83	Seed treatment: ethirimol 82	ethirimol 83	triadimenol 82	triadimenol 83	triforine 82	triforine 83
Before herbicide	2	3	2	1	0	0	0	0
With herbicide	90	86	40	45	19	29	61	73
After herbicide	8	11	58	54	81	71	39	27
Survey area (ha) 1982	28,072		12,057		4,493		3,378	
Survey area (ha) 1983	17,229		9,499		4,269		976	

Where a mildew seed treatment had not been used, most first sprays of fungicide were applied with the herbicide (Table 5). Most first mildew sprays on triadimenol or ethirimol seed treated crops were applied after the herbicide.

In 1983 much less Golden Promise without mildew seed treatment was sprayed first with triadimefon than in 1982, with an almost corresponding increase in the area first sprayed with fenpropimorph (Table 6). There was much less change where mildew seed treatments had been used. Triadimefon and propiconazole were more widely used after the unrelated ethirimol seed treatment than after the related triadimenol seed treatment. However, around one-third of the triforine seed treatment was first sprayed with one of these related fungicides in both years.

TABLE 6
First mildew sprays on Golden Promise in relation to mildew seed treatment (percentage area within seed treatment sprayed)

	No seed treatment		Seed treatment					
			ethirimol		triadimenol		triforine	
First spray	82	83	82	83	82	83	82	83
triadimefon	46	13	23	14	7	2	26	23
propiconazole	9	6	17	16	4	6	10	6
fenpropimorph	28	55	41	48	73	76	48	68
tridemorph	16	18	17	16	14	12	16	3
others	1	8	2	6	2	4	0	0
Survey 1982	28,594		12,119		4,452		3,398	
area (ha) 1983	17,285		9,578		4,173		976	

In 1982 there were very large differences in the popularity of the various fungicides as first and second sprays on Golden Promise without seed treatment (Table 7). This reflected growers' experience of poor mildew control with some fungicides (Table 8) and the specific advice given in such circumstances. In 1983 fenpropimorph and tridemorph together accounted for around 70 per cent of both the first and second sprays on Golden Promise without mildew seed treatment.

TABLE 7
First and second mildew sprays on Golden Promise without mildew seed treatment (percentage area sprayed)

	First sprays		Second sprays	
Fungicide	82	83	82	83
triadimefon	46	13	4	3
propiconazole	9	6	5	8
fenpropimorph	28	55	59	48
tridemorph	16	18	27	21
others	1	8	5	20
Survey 1982	28,580		17,435	
area (ha) 1983	17,285		8,621	

Fungicide mixtures were not a significant feature in 1982, accounting for less than ½ per cent of first sprays and 5 per cent of second sprays overall. In 1983 mixtures accounted for 6 per cent of first sprays and 14 per cent of second sprays on Golden Promise without mildew seed treatment. These mixtures were mostly triadimefon or propiconazole plus tridemorph, but 1½ per cent of the Golden Promise without mildew seed treatment that was sprayed twice, was sprayed with fenpropimorph plus triadimefon.

TABLE 8
Growers' mildew control ratings for first sprays on Golden Promise without mildew seed treatment (percentage area within first spray)

Mildew control	triadimenol 82	triadimenol 83	propiconazole 82	propiconazole 83	fenpropimorph 82	fenpropimorph 83	tridemorph 82	tridemorph 83
Excellent	4	27	4	16	43	41	28	28
Good	20	35	12	43	41	50	41	66
Satisfactory	30	24	23	25	12	8	21	5
Poor	33	14	33	8	3	1	7	1
Very poor	13	0	28	8	1	0	3	0
Survey area (ha) 1982	12,976		2,383		7,998		4,543	
Survey area (ha) 1983	2,301		931		9,183		3,099	

Growers rated all first sprays better for mildew control in 1983 than in 1982 (Table 8). The improvement was most marked for triadimefon and propiconazole, but the eradicant fungicides fenpropimorph and tridemorph were still rated more highly.

In 1982 all fungicides performed better on the more mildew resistant cultivars: poor control with some fungicides was a problem primarily on the highly susceptible cultivar Golden Promise. A similar trend was observed in 1983, but a full comparison could not be made because such a small area of the more resistant cultivars was first sprayed with either triadimefon or propiconazole.

TABLE 9
Second sprays on Golden Promise without mildew seed treatment in relation to first spray (percentage of area sprayed twice)

Second spray	First spray: triadimefon 82	triadimefon 83	propiconazole 82	propiconazole 83	fenpropimorph 82	fenpropimorph 83	tridemorph 82	tridemorph 83
triadimefon	0	0	5	0	5	4	12	7
propiconazole	5	2	0	0	10	19	5	1
fenpropimorph	72	74	41	30	39	28	56	71
tridemorph	18	15	54	27	37	35	23	10
others	5	9	0	43	9	14	4	11
Survey area (ha) 1982	8,758		2,021		2,692		3,648	
Survey area (ha) 1983	1,345		795		3,050		2,415	

Where triadimefon was sprayed first on Golden Promise without mildew seed treatment, fenpropimorph was the most common second spray in both years (Table 9). Where propiconazole was the first spray, tridemorph and fenpropimorph were the predominant second sprays. In 1983, however, a significant proportion of the area sprayed first with propiconazole was later sprayed with the less commonly used fungicides or with fungicide mixtures. A wider range of second sprays was used after a fenpropimorph first spray, especially in 1983. Where tridemorph was first sprayed, fenpropimorph was the most common second spray, especially in 1983. Where a fungicide mixture was first applied, 82 per cent of the area sprayed twice was again sprayed with a mixture.

DISCUSSION

The 1983 survey showed that Golden Promise maintained its popularity throughout south-east Scotland: growers attached more importance to the cultivar's desirable earliness and good head retention and its suitability for malting, than to the problems of mildew control in 1982. The overall pattern of mildew fungicide usage was very similar in both years although the patterns of disease development differed. In 1982, an early season, 45 per cent of spring crops in south-east Scotland were infected with mildew by 15 May: in 1983, when wet weather delayed early season growth and mildew development, only 20 per cent of crops were infected by mid-May. It is thus possible that most of the first sprays applied with the herbicide in 1983 were in fact applied when mildew levels were much lower than in 1982.

While it is understandable that growers, following their experiences in 1983, should swing away from the triazole fungicides which lack a marked eradicant effect and to which the local mildew population may have become less sensitive, it is of concern that so much of the spring barley in 1983 was sprayed, often twice, with the morpholine fungicides, fenpropimorph and tridemorph. Growers were specifically warned that such a move might well just create new problems. The increasing use of fungicide mixtures is, however, an interesting development, despite the lack of interest in cultivar mixtures.

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FUNGICIDES FOR THE CONTROL OF RIPENING DISEASES IN WINTER WHEAT

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ABSTRACT

A range of commercially available fungicides was compared in three field experiments for the control of ripening diseases in winter wheat. The main diseases present were mildew (*Erysiphe graminis*), *Septoria nodorum* and the secondary pathogens grey mould (*Botrytis cinerea*), sooty mould (*Cladosporium herbarum*) and *Fusarium* spp. Disease severity and the relative importance of each disease present varied between the experiments. Nevertheless the highest yield responses of 1.10, 1.07 and 0.72 t/ha in 1981, 1982 and 1983 respectively consistently followed the use of fungicides with a broader spectrum. Yield responses were mainly the consequence of increases in mean grain weight.

INTRODUCTION

Yarham (1980) classified ripening diseases of wheat into three main groups:

1. Major diseases such as rusts (*Puccinia striiformis* and *P recondita*), mildew (*Erysiphe graminis*) and *Septoria nodorum* and *S tritici*.

2. Those fungi whose attacks are stimulated by the flowering process such as grey mould (*Botrytis cinerea*), *Fusarium* and *Alternaria*.

3. The minor parasites which, irrespective of the presence of pollen, invade the tissue of the ageing leaf and accelerate the natural process of senescence. Examples are *Ascochyta gramineum*, *Didymella exitialis* and sooty moulds (*Cladosporium herbarum*).

Septoria nodorum and *S.tritici* and the minor pathogens of groups 2 and 3 are all favoured by wet weather. These diseases together with mildew are often found at high levels on the upper leaves and ears of winter wheat crops at Rosemaund EHF. The cost effectiveness of late season fungicide applications at Rosemaund was clearly demonstrated in an earlier series of experiments reported by Clare *et al* (1981).

The experiments reported here compare the disease control and yield responses obtained from a range of fungicides and fungicide mixtures.

MATERIALS AND METHODS

The experiments reported were sited at Rosemaund EHF on silty loam to silty clay loam soils of the Bromyard and Middleton soil series. The soil although structurally unstable is water retentive and predominantly of 1-2 m depth. Altitude is 84 m with an average annual rainfall of 664 mm.

The experiments were carried out from 1981 to 1983 on the cultivar Avalon grown as a first wheat following grass leys to avoid complications in interpretation due to eyespot or take-all infections. The experimental design was a randomised block with four replicates. Plot size was 50 m^2.

Fungicide treatments	Rate of application kg/ha ai
0. nil (control)	
1. captafol	1.4
2. chlorothalonil	1.0
3. iprodione	0.5
4. triadimefon	0.125
5. fenpropimorph	0.75
6. triadimefon + captafol	0.125 + 1.4
7. fenpropimorph + chlorothalonil + carbendazim	0.75 + 1.0 + 0.3
8. fenpropimorph + iprodione + thiophanate methyl	0.75 + 0.5 + 0.3
9. carbendazim + maneb + triadimefon	0.25 + 1.8 + 0.06
10. prochloraz	0.4
11. propiconazole	0.25

Treatments 4 and 5 were not included in 1981.
Treatment 8 - mixture without thiophanate methyl in 1981.
Treatment 9 - mixture without triadimefon in 1981.

Date and crop growth stage at spraying

Experiment	Year	Date of fungicide application	Growth stage
1	1981	8 June	55 - 60
2	1982	7 June	55 - 60
3	1983	21 June	60 - 65

All the fungicide treatments were applied once only using an Oxford Precision Sprayer fitted with 110^{o} hydraulic fan nozzles with a capacity of 1.17 l/min at 3 bars, operated at 3 bars with a travel speed of 5.5 km/hr applying 255 l/ha.

No other fungicides were applied to the experiments except for experiment 1 in 1981 when 0.125 kg/ha ai triadimefon was used over all treatments at GS 31 (5 April).

Assessments

Leaf and ear diseases and green leaf area were assessed at intervals following treatment applications using the "Guide for assessments of cereal diseases" prepared by Plant Pathology Laboratory, Harpenden. Observations were made on 10 tillers taken at random from each plot.

An area of 44.1 m^2 was harvested from each plot, fresh weight of grain recorded and a sample oven-dried for an estimate of moisture content and mean grain weight.

RESULTS

Experiment 1 (1981)

TABLE 1

Yield and mean grain weight responses and disease assessments (22 July 1981)

Fungicide treatment	Yield response (t/ha at 85% DM)	Mean grain wt response ($g x 10^{-3}$)	Septoria nodorum (%) leaf 1	Septoria nodorum (%) leaf 2	Mildew (%) leaf 1	Mildew (%) leaf 2	Mildew (%) ear
	(SED ± 0.231)	(SED ± 1.03)					
0.	(7.97)	(43.7)	5.8	43.8	3.3	3.5	1.6
1.	0.43	1.2	4.0	32.1	2.3	3.2	0.8
2.	0.57	2.1	4.9	24.0	3.1	4.6	1.3
3.	0.71	2.3	4.4	17.2	0.8	1.1	0.9
4.) 5.)	not included in experiment 1						
6.	0.95	4.2	6.6	27.2	0.7	0.3	0.9
7.	1.10	4.5	2.9	14.4	0.6	1.1	0.0
8.	0.97	3.7	4.4	16.2	0.1	0.3	0.0
9.	0.77	3.7	3.8	24.1	0.7	3.5	0.2
10.	0.84	-1.0	4.4	23.7	1.2	3.4	0.3
11.	0.95	4.3	5.1	17.3	0.4	0.5	0.2

S.nodorum was encouraged by wet weather during May when 87 mm rain fell on 24 rain days. Consequently infections were already well developed at the time of spraying. The assessments of S.nodorum on leaf 2 indicate that captafol applied either on its own or in a mixture with triadimefon had poorer curative activity than iprodione, chlorothalonil or propiconazole.

Despite the low levels of mildew the broad spectrum mixtures of fungicides, with their ability to control mildew, almost doubled the yield response from approximately 0.50 t/ha obtained from the control of S.nodorum to 1.00 t/ha. Yield responses were directly related to increased mean grain weights.

Experiment 2 (1982)

Foliar disease levels remained very low up to the flag leaf stage due to a combination of a very cold winter with little growth or disease carry over coupled with very dry weather in April and May. However June was very wet with 175 mm rain falling on 21 rain days, some at high intensities. This resulted in a rapid build-up of ear diseases including glume blotch and ear blight, Fusarium poae and grey and sooty moulds; mildew remained at low levels. (See Table 2).

Fungicide treatments were applied at the start of the wet weather period in June and therefore this was a test of rainfastness and protectant activity rather than curative action. Chlorothalonil, captafol and particularly propiconazole gave good control of glume blotch and maintenance of green ear tissue. Accurate assessments of Fusarium spp and grey mould proved impossible. However the results obtained showed a slight reduction in these diseases following the use of an MBC generating fungicide. The highest yield responses were again given by the more broad spectrum fungicides and were related to increases in mean grain weights.

TABLE 2

Yield and mean grain weight responses and disease assessments (6 July 1982)

Fungicide treatment	Yield response (t/ha at 85% DM)	Mean grain weight response (gx10^{-3})	*Septoria nodorum* (%) leaf 1	*Septoria nodorum* (%) leaf 2	*Septoria nodorum* (%) ear	Mildew (%) leaf 1	Green tissue ear (%)
	(SED ±0.236)	(SED ±1.04)	(SED ±3.38)	(SED ±6.05)	(SED ±7.17)	(SED ±0.67)	(SED ±5.60)
0.	(7.08)	(33.6)	1.4	44.0	58.7	4.0	21.9
1.	0.65	3.0	1.0	26.9	12.5	3.2	53.8
2.	0.08	2.1	0.9	24.0	7.0	4.2	48.8
3.	0.13	2.5	0.8	32.3	35.0	2.1	33.8
4.	0.14	1.7	1.2	38.8	45.0	0.9	31.3
5.	0.20	2.3	1.9	37.4	48.7	0.9	28.8
6.	0.86	4.6	1.1	25.4	13.5	1.3	58.8
7.	0.65	3.9	0.7	17.5	4.0	1.3	61.3
8.	0.73	3.0	0.8	21.8	17.0	0.7	45.0
9.	0.78	3.2	0.8	19.9	23.5	1.1	43.8
10.	0.56	4.0	0.6	12.4	25.5	0.9	51.3
11.	1.07	5.3	0.9	16.6	2.4	2.4	66.3

Experiment 3 (1983)

TABLE 3

Yield and mean grain weight responses and disease assessments (14 July 1983)

Fungicide treatment	Yield response (t/ha at 85% DM)	Mean grain weight response (gx10^{-3})	*Septoria nodorum* (%) leaf 1	*Septoria nodorum* (%) leaf 2	Mildew (%) leaf 1	Mildew (%) leaf 2	Mildew (%) ear	Yellow* (%) leaf 1
	(SED ±0.168)	(SED ±0.52)	(SED ±0.54)	(SED ±3.31)	(SED ±0.37)	(SED ±1.41)	(SED ±1.60)	(SED ±3.7)
0.	(7.00)	(39.4)	2.0	27.9	1.8	7.2	11.9	23.9
1.	0.24	1.4	1.0	21.4	1.4	6.6	7.0	18.2
2.	0.15	1.8	0.9	20.9	2.4	10.7	9.7	15.7
3.	0.01	1.3	0.8	18.9	1.5	8.7	4.8	26.7
4.	0.28	0.6	1.1	25.2	0.8	2.9	4.1	12.5
5.	0.49	1.3	1.6	22.6	0.6	2.4	2.3	16.7
6.	0.63	2.8	0.7	16.8	0.8	3.8	4.4	10.2
7.	0.72	3.3	0.5	15.4	0.2	1.4	1.4	7.5
8.	0.66	3.1	0.5	12.5	0.8	2.5	1.3	28.0
9.	0.61	2.7	0.8	16.5	0.6	4.1	2.7	6.7
10.	0.24	1.7	0.7	12.9	1.3	5.4	3.3	18.0
11.	0.66	2.3	0.5	13.2	0.3	2.8	2.5	17.0

* % yellow - this is an indication of the area of leaf in which chlorophyll had either ceased to be active or had been destroyed by early senescence due to phytotoxic effects of the sprays applied.

Warm and dry weather in May and June encouraged mildew but curtailed the development of Septoria spp. Fenpropimorph and mixtures containing it gave good control of foliar and ear mildew. Triadimefon and mixtures containing it were slightly less effective in terms of mildew control. The differences in mildew control were reflected in the pattern of yield responses obtained. Propiconazole (applied at 0.25 kg/ha ai) again gave good mildew control.

The highest yield responses and greatest increases in mean grain weight were again provided by fungicides with broader spectra and their mixtures despite only low levels of Septoria spp and other pathogens.

Effects of fungicides on green tissue

Several fungicides prolonged the maintenance of green tissue of the flag leaf and ear in a manner not apparently related directly to efficacy of disease control. These effects were most obvious in experiment 3 when the treatments were applied during a very warm and dry weather period (see TABLE 3).

Although fungicides generally delayed the loss of green tissue mixtures containing MBC generating compounds tended to be most effective in this respect. The exception was the mixture of thiophanate methyl with fenpropimorph and iprodione. This treatment together with iprodione alone appeared to cause dewaxing. It is conceivable that, in the conditions of high transpiration demand and heat induced water stress experienced in experiment 3, dewaxing will increase transpiration losses, thereby accelerating tissue death and senescence. This may also have implications for tank mixtures of fungicides when several wetting agents are inevitably added to each other.

DISCUSSION

Applying ADAS guidelines to these experiments as given in 'The use of fungicides and insecticides on cereals 1984' (MAFF 1984) an application of fungicide was warranted at this site each year. The results confirm the cost effectiveness of this fungicide application. Despite the large year to year variation in the severity of each disease the correct decision was to apply a broad spectrum fungicide or fungicide mixture. On average there was little difference in yield response between the broad spectrum materials but important differences in efficacy against particular diseases were observed.

Of the contact materials chlorothalonil and captafol provided similar protection against Septoria nodorum. Iprodione was rather more inconsistent giving good Septoria nodorum control on the leaves in experiment 1 but poorer control, particularly of glume blotch, when very wet weather followed application in experiment 2.

In the very wet conditions experienced in experiment 2 when Septoria nodorum reached high levels ultimately colonising the ear as glume blotch propiconazole gave outstanding disease control. Although prochloraz, was, in this case, equally effective in controlling Septoria nodorum on the leaves, control of glume blotch was inferior.

Fungicides containing fenpropimorph tended to provide more rapid control of mildew than those based on triadimefon, propiconazole and prochloraz. However the performance of triadimefon and propiconazole was similar to that of fenpropimorph when mildew levels were low at application. Prochloraz gave poor control of mildew.

The role of MBC generating fungicides in late season disease control should also be considered. Carbendazim + maneb + triadimefon which relies on carbendazim at least in part for Septoria spp control gave good protection against severe Septoria nodorum infections on the leaves and glumes in experiment 2. There was also evidence in experiment 3 that the inclusion of MBC generating materials in fungicide mixtures was an aid in delaying leaf senescence.

Most fungicide treatments significantly improved mean grain weight, the average increase was 6.4, 9.6 and 5.1 per cent in 1981, 1982 and 1983 respectively. This compares favourably with the 1.9 per cent average increase reported by Cooke (1980) from 118 experiments testing mainly single sprays of MBC generating fungicides applied from the start of flag leaf emergence until the milky ripe stage.

This increase in individual grain size was the yield component responsible for much of the grain yield response recorded as shown by the linear regression of grain yield against mean grain weight which accounted for 84, 70 and 68 per cent of the grain yield variance in 1981, 1982 and 1983 respectively. This improvement in grain size can increase the value of the grain at sale.

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RELATIONSHIPS OF CULTIVAR, SOWING DATE, AND FUNGICIDE TREATMENT TO PROGRESS OF SEPTORIA TRITICI BLOTCH AND SEPTORIA NODORUM BLOTCH IN ONTARIO WINTER WHEAT

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ABSTRACT

Etaconazole used as a seed treatment and propiconazole applied as a foliar spray on 30 October markedly reduced progress of septoria tritici blotch (Mycosphaerella graminicola) on wheat cv. Favor in the autumn and under snow cover in winter. However these treatments did not reduce disease intensities estimated on 27 April or later and failed to increase yields. Propiconazole applied on 17 May (GS 30) reduced intensities of tritici blotch and nodorum blotch (Leptosphaeria nodorum) on flag leaves and spikes as late as 6 and 9 July, respectively, and increased yield by 26%. Propiconazole applied on 17 May and 17 June (GS 65) markedly reduced disease intensity and increased yield by 42%. Delay in sowing in autumn reduced pycnidial intensities in the following April but not in June. Yield responses to propiconazole were high in cv Augusta, Favor, and Houser, but low in cv Fredrick and breeding line 384-01.

INTRODUCTION

Septoria tritici blotch (Mycosphaerella graminicola) and septoria nodorum blotch (Leptosphaeria nodorum) rank among the most destructive foliar diseases of winter wheat in Ontario. Provincial recommendations for managing these diseases include crop rotation, burial of wheat debris by ploughing and fungicidal seed treatments. Serious epidemics of the septoria blotches have been frequent even though the recommended management practices have been widely applied. Alternative approaches to managing the diseases are needed.

In the present study, wheat cultivar, sowing date, and specifically-timed fungicide sprays were investigated in relation to disease progress and yield. The cultivars include Fredrick, the principal cultivar grown in Ontario, and several newer cultivars introduced during 1980-83. Fungicides are not yet registered in Canada for application against the septoria blotches. However studies on the effects of fungicides on epidemics of the septoria blotches and on wheat yields are justified to provide data for registration purposes and maximizing efficiency of fungicide use in the event of registration.

MATERIALS AND METHODS

General procedures

Winter wheat was grown in field plots near Guelph, Ontario, in 1981-82 and 1982-83. Treatments in each experiment were arranged in a randomized block design with four replicates. Fertilizer applications were 5-20-20 N:P:K at 350 kg/ha before sowing and 80 kg N/ha in mid-April. Disease intensity was estimated on leaf laminae or on the spikes according to % area that appeared discoloured or the % area on which pycnidia were visible (Horsfall and Cowling, 1978). Yields were estimated at maturity. All data were analysed by Duncan's new multiple range test and significance is reported at P = 0.05.

Foliar fungicides 1981-82

Winter wheat cv. Favor was sown in plots (40 m x 4 m) on 15 September 1981. Wheat representing conventional practices was treated with carboxin (0.53 g a.i./kg seed) only. Wheat in all other treatments was grown from seed treated with etaconazole (0.05 g a.i./kg seed). These plots were sprayed with propiconazole (125 g a.i./ha) on 30 October or on 17 May (GS 30) or 17 June (GS 65). Other plots were sprayed on both dates in spring, or on the autumn and spring dates, or on 30 October, 6 and 25 May, 14 June and 7 July. All sprays were applied in 200 L water/ha using a self-propelled sprayer equipped with a 4-m boom and Tee-jet No. 8002 nozzles and operated at 195 kPa.

Sowing date and cultivar 1982-83

Cultivar Fredrick was sown in plots (6 m x 1.3 m) at weekly intervals from 12 September to 3 October. Disease was assessed on 17 October, 14 November, 19 April and 7 June. Leaves assessed on 17 October were plated on paraquat agar (Bannon 1978). To determine potential inoculum on 19 April leaves with pycnidia in four 25 cm portions of row per plot were harvested, shaken in water, and liberated conidia were counted.

Cultivar and foliar fungicides 1982-83

In plot area A four cultivars were grown in 4 m x 3 m plots and supplied with 55 kg N/ha in mid April and at GS 33. The wheat was sprayed with ethephon (560 g a.i./ha) at GS 41 and with the following fungicides at GS 61-65 (23 June): propiconazole (125 g a.i./ha), chlorothalonil (500 or 100 g a.i./ha), propiconazole (125 g a.i./ha) plus chlorothalonil (500 g a.i./ha), triadimefon (125 (g a.i./ha), and triadimefon (125 g a.i./ha) plus chlorothalonil (500 g a.i./ha). Fungicides were applied in 300 L water/ha at 200 kPa by means of an air-pressurized, backpack sprayer equipped with a 2-m boom and four hollow-cone D2-13 nozzles. In plot area B four cultivars and a breeding line were grown in 3 m x 1.3 m plots and sprayed with propiconazole (125 g a.i./ha) at GS 25-29 (13 May), GS 31-32 (27 May) and GS 55-60 (22 June). Fungicides were applied as in area A.

RESULTS

Foliar fungicides 1981-82

Chlorotic flecks and small lesions (<3 mm) of tritici blotch but no pycnidia of M. graminicola were observed on 29 October. Leaf discoloration was significantly lower in etaconazole-treated wheat (9%) than in untreated wheat (24%). Pycnidia developed on 32±8%, 26±7% and 7±4% of the lower leaves of untreated wheat, carboxin-treated wheat and etaconazole-treated wheat, respectively, when the leaves were incubated in a moisture chamber for 10 d.

Pycnidia were abundant on leaves of untreated and carboxin-treated wheat immediately after the period of snow cover and freezing which persisted from mid-November until early April (Table 1). Etaconazole markedly reduced areas of leaves with pycnidia on 12 April but not on 27 April or later in the growing season. Propiconazole applied on 30 October reduced leaf areas with pycnidia on 12 and 27 April but not at later times of assessment.

TABLE 1

Effects of systemic fungicides applied to seed or foliage of winter wheat cv. Favor on estimated areas of leaves with pycnidia of Septoria spp. at various times in the 1981-82 growing season.

Fungicide treatments				Estimated % area with pycnidia				
	Foliar (Propiconazole)			Leaf 2†		Penult. Leaf	Flag Leaf	Spike
				12 Apl.	27 Apl.	6 July	6 July	9 July
Seed	30 Oct.	17 May	17 June	(GS 22)	(GS 23)	(GS 83)	(GS 83)	(GS85)
None	-	-	-	8.5 c	11 b	44 ef	8 d	54 d
Carboxin	-	-	-	9.4 c	13 b	47 f	8 d	55 d
Etaconazole	-	-	-	2.5 b	11 b	48 f	8 d	50 d
Etaconazole	+	-	-	0.1 a	2 a	40 def	7 d	50 d
Etaconazole	-	+	-	-	-	38 de	4 bc	38 c
Etaconazole	-	+	+	-	-	22 c	3 abc	16 ab
Etaconazole	+	+	+	-	-	18 bc	2 abc	18 b
Etaconazole	(Five sprays)			-	-	14 ab	1 ab	11 a

† Second most recently expanded leaf on main tiller.

Propiconazole applied on 17 May significantly reduced pycnidial intensities on the flag leaves (6 July) and spikes (9 July), but not on the penultimate leaves (22 and 29 June, 6 July) (Table 1). Propiconazole applied on both 17 May and 17 June markedly reduced pycnidial intensities on the penultimate and flag leaves, and on the spikes. Disease intensities during June and July in wheat sprayed in both autumn and spring were similar to those in wheat sprayed only in the spring. After spike emergence both nodorum blotch and tritici blotch were present.

The seed treatments and autumn application of propiconazole did not increase yields. Total yields of wheat sprayed with propiconazole were 26%, 42%, and 39% higher than in nonsprayed etaconazole-treated wheat when the sprays were applied once (17 May), twice (17 May and 17 June) or three times (30 October, 17 May and 17 June), respectively. Five applications increased yield by 39%.

Sowing date and cultivar, 1982-83

M. graminicola completed one infection cycle during the autumn growing period in wheat sown on 12 and 19 September, but not in wheat sown on 26 September or 3 October (Table 2). Leaf areas with pycnidia increased after plating on paraquat agar from 8.7 to 29% in wheat sown on 12 September and sampled on 17 October. No pycnidia appeared on wheat sown on 26 September or 3 October but a few developed in samples of 14 November when plated. Leaf areas with pycnidia on 19 April (after snow cover and freezing) were markedly higher than in late autumn. On April 19, pycnidial intensities and numbers of spores/m^2 plot were progressively lower in wheat of successive sowing dates. On 7 June, pycnidial intensities on penultimate leaves did not differ among treatments but leaf discoloration was lower in later-sown wheat. Yields increased significantly and lodging intensity decreased with each 7-d delay in sowing date.

TABLE 2

Effects of sowing dates in 1982 of winter wheat cv. Fredrick on estimated pycnidial intensities of *Mycosphaerella graminicola*, estimated leaf area discolored, and potential inoculum of *M. graminicola* in April, 1983.

Sowing date	% leaf area with pycnidia†			Discoloration of penultimate leaf (%) (7 June)	Log_{10} spores/m^2 plot (19 Apl.)
	17 Oct.	19 Apl.	7 June		
12 Sept.	8.7 b	55 d	5	24 c	8.2§
19 Sept.	0.1 a	31 c	4	16 ab	7.6
26 Sept.	0.0 a	18 b	4	15 ab	7.1
3 Oct.	0.0 a	3 a	3	11 a	4.6

† Lowest leaf (17 Oct. and 19 Apl.) and penultimate leaf (7 June).
§ Standard error for the difference between two treatment means is 0.75.

Cultivar and foliar fungicides, 1982-83

In plot area A the various fungicides failed to reduce or only marginally reduced % discoloration of the penultimate and flag leaves during June and July, and did not increase 1000-grain weights. No rain fell in the period from 7 June (GS 45) to maturity in early August and temperatures were often high (>30C). Leaf discoloration was associated with stress. Plot area B received some showers after 7 June. According to pycnidial intensities on leaf 3 estimated on 5 July, the septoria blotches were less severe in cv Fredrick and line 384-01 than in the other cultivars (Table 3). Similar observations were made in the final assessments for leaf 4 (21 June) and for the penultimate leaf (12 July). Logistic infection rates (r) on leaf 3 or leaf 4, however, were not significantly different during the periods of disease estimations.

Propiconazole markedly reduced pycnidial intensities in all cultivars and significantly increased yield of cv Augusta, Favor and Houser, but not of Fredrick or line 384-01 (Table 4).

TABLE 3

Progress of septoria tritici blotch in five cultivars of winter wheat.

Cultivar or line	Height of leaf 3 (cm)†	Estimated % area of leaf 3 with pycnidia				r values†† (14 June-5 July)
		14 June	21 June	28 June	5 July	
Augusta	32±7	0.8 bc	7 b	20 a	51 b	0.23
Favor	38±5	1.0 bc	8 b	23 a	51 b	0.24
Fredrick	35±6	1.6 c	3 a	15 a	34 a	0.17
Houser	33±4	1.5 c	12 c	34 b	66 c	0.23
384-01	33±4	0.3 ab	2 a	14 a	37 a	0.27

† Height of auricles above soil ± standard deviation.
†† Logistic infection rate, $r = 1/t_2 - t_1. (\text{logit } x_2 - \text{logit } x_1)$.

TABLE 4

Effects of three foliar sprays of propiconazole on progress of septoria blotches and yield in various cultivars of winter wheat.

Cultivar or line	Estimated % leaf area with pycnidia				Total yield t/ha		% yield increase
	Leaf 3 (28 June)		Leaf 2 (5 July)				
	Check	Sprayed	Check	Sprayed	Check	Sprayed	
Augusta	20 b††	0.4 a	15 c	0.2 a	7.0 de	7.9 f	12.9
Favor	23 b	0.1 a	10 b	0.6 a	5.6 ab	6.4 de	14.3
Fredrick	15 b	0.0 a	8 b	0.0 a	5.3 a	5.6 abc	5.7
Houser	34 c	0.0 a	9 b	0.0 a	6.6 cd	7.7 ef	16.7
384-01	14 b	0.1 a	6 b	0.0 a	6.3 bcd	6.6 cd	4.8

DISCUSSION

Tritici blotch progressed in two main phases during October to April and after spike emergence (mid-June to late July). Extensive symptoms and abundant pycnidia developed while the wheat was under the snow. Nodorum blotch was observed only after spike emergence. In 1981-82 both the etaconazole seed treatment and the autumn application of propiconazole markedly suppressed pycnidial production during the winter. The period of epidemiologic impact (sensu Sutton and Steele 1983) of etaconazole was > 209 days. The fungicides reduced the number of colonies of M. graminicola in the autumn and thus the number of sites for progressive colonization and sporulation when under snow cover.

Etaconazole, the autumn application of propiconazole, and a delay in sowing date each reduced pycnidial intensities in April, but not at later times of assessment. This indicated that disease progress in the fungicide-treated and late-sown wheat apparently accelerated in spring and compensated for less inoculum in April. A similar phenomenon was observed earlier (Sutton and Steele 1983). The period of epidemiological impact of propiconazole applied on 17 May was at least 50 to 53 days while treatments with final sprays on 17 June reduced pycnidial intensities 19 or 21 days later. Long epidemiologic impact may be related to activity of propiconazole in reducing inoculum production on the lower leaves as well as in protecting the upper canopy.

The various fungicide treatments in 1981-82 increased yields only when applied in spring. Though etaconazole and the autumn application of propiconazole effectively managed severe tritici blotch which developed under snow cover, these treatments failed to increase yield. The highest yield response to propiconazole occurred after two applications (GS 30 and GS 65). Data of 1982-83 indicate that single applications of fungicides do not promote yields during dry seasons when disease progress is slow and the wheat is stressed by high temperatures and water shortage.

The lower intensity of the septoria blotches in cv. Fredrick and breeding line 384-01 than in other cultivars (1982-83) indicated presence of rate-reducing resistance but this was not substantiated by estimates of r. Lower disease intensity possibly was a function of delay in initial disease increase. Delayed blotch increase in 384-02 may be related to slower plant development in this line. Though intensity of the septoria blotches on the flag and penultimate leaves was only moderate in 1983, propiconazole promoted yield substantially in cv. Augusta, Favor, and Houser. Use of the fungicide may be justified on those cultivars but not on Fredrick or 384-01.

ACKNOWLEDGEMENTS

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EFFECTS OF FUNGICIDES AND THEIR TIMING ON PLANT BIOMASS, DISEASE AND YIELD OF WINTER BARLEY

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ABSTRACT

November applied fungicides decreased powdery mildew (*Erysiphe graminis*) during autumn and winter, and increased plant dry matter production by early spring (GS 30) by 28 - 74 per cent. There were no yield increases from these autumn fungicide applications when followed by 2 later spring sprays (prochloraz, GS 31 + propiconazole GS 39) compared with 2 later spring sprays alone. Fungicides and experimental fungicide mixtures applied at GS 31 and GS 39 controlled foliar diseases, prolonged the duration of green leaf areas and increased yield. Powdery mildew inoculum was suppressed most by fungicide mixtures that contained fenpropimorph.

INTRODUCTION

Barley diseases have many causes and may result in considerable reductions in grain yield and quality. Losses vary with the nature of the pathogen, the timing and intensity of attack and environmental stresses. Several foliar diseases have serious consequences in winter barley growing, these are net blotch (*Pyrenophora teres*), leaf blotch (*Rhynchosporium secalis*), powdery mildew (*Erysiphe graminis*) and brown rust (*Puccinia hordei*). Detailed studies have been made on the effects of fungicides against each of these major fungal diseases (Jordan, Tarr & Miles 1982, Jordan & Best 1981, 1984). However, winter barley crops, in the field, are seldom affected by only one disease. Often, three or more diseases may be present, sometimes in small amounts which individually may not be considered damaging, but whose additive effects and interactions may affect yield and response to fungicides.

This paper presents data on effects of autumn and spring fungicide sprays on disease, green leaf area and yield and evaluates some experimental fungicide mixtures aimed to increase the spectrum of foliar disease control over that provided by each individual component.

MATERIALS AND METHODS

A field experiment was done on mid-September-sown winter barley, cv. Igri at Long Ashton Research Station (LARS). Fifteen different fungicide treatments were applied (Table 1), arranged in randomised blocks (plot size 12m x 4m) with 3 replications. Plots that received the fungicide triadimefon were buffered either side by a 4m unsprayed barley plot. The fungicide treatments were applied at manufacturers' recommended concentrations (unless otherwise stated) with an Oxford Precision Sprayer fitted with a 2m boom, and working at 200 KPa pressure using 110^{o} flat fan nozzles to apply 250 l/ha.

The following treatments were applied:

TABLE 1

Fungicide treatments and amounts used (g a.i./ha)

November-treatments (followed by an overspray of prochloraz (400) GS 31 (3.4.84) + propiconazole (125) GS 39 (8.5.84))

Fungicide	Product	rate (g a.i./ha)
Fenpropimorph	Corbel	750
Prochloraz	Sportak	400
Propiconazole	Radar	125
Triadimefon	Bayleton	125
*RH 3866	experimental	125
Unsprayed (November)	-	-

Spring-applied fungicides (each applied at GS 31 and GS 39)

Fungicide	Product	rate (g a.i./ha)
Prochloraz	Sportak	400
Propiconazole	Tilt	125
Pyrazophos	Afugan	600
*RH 3866	experimental	125
*Fenpropimorph and chlorothalonil	Corbel:Bravo	750:600
*Fenpropimorph and iprodione	Mistral:Rovral	750:1000
*Fenpropimorph and prochloraz	Corbel:Sportak	375:200
*Triadimenol and prochloraz	Bayfidan:Sportak	125:200
*Triadimenol and propiconazole	Bayfidan:Tilt	125:63

* The experimental fungicide mixtures were selected from detailed laboratory and glasshouse tests for protectant, eradicant and antisporulant action against powdery mildew, leaf blotch and net blotch under wet and dry conditions (Jordan & Best 1984, 1985 in press).

Foliar diseases were identified and assessed in autumn and at frequent intervals in spring and summer by estimating the diseased and green areas (%) on the topmost leaves of 10 main stems removed at random from each plot. Additionally, 5 main stems in each plot were labelled at GS 31, immediately prior to spray application. On these stems the green areas (%) and leaf areas affected by each disease identified were recorded, in situ, at approximately weekly intervals throughout the spring and summer.

A volumetric spore trap mounted on wheels (Brook 1959) was used to sample a designated area (12m x 0.25m) across each plot at regular intervals in autumn and spring. Conidia caught on glass microscope slides coated with petroleum jelly, were identified and counted after staining with lactophenol-trypan blue.

To determine the effect of November-applied sprays on dry matter production, 10 plants were removed from each plot in February and March, dried in an oven at 80°C for 36h and weighed.

At harvest, July 1984, whole plots were harvested with a Claas Compact combine, 2.15m cut. Plot yields were weighed on the combine and samples taken for moisture determination.

RESULTS

November-applied fungicides

On 10 November 1983 (GS 25) immediately prior to spraying, powdery mildew affected 5,25 and 63% of the area of leaves 2,3 and 4 respectively: amounts of leaf blotch and net blotch were low (<1%). Prochloraz, fenpropimorph and propiconazole decreased the number of mildew conidia caught in the spore trap 5 days post spraying by 72,61 and 56% respectively compared with unsprayed. By mid-February counts of mildew conidia were lower only on the plots sprayed in November with fenpropimorph (Table 2).

TABLE 2

Effects of November-applied fungicides on inoculum of E. graminis

Fungicide treatment applied GS 25	Mildew spores caught/litre days post GS 25 spray 2d	5d	100d
unsprayed	31.6a	40.9a	118.5a
fenpropimorph	17.7b	16.1c	78.2b
prochloraz	30.8a	11.4c	105.3a
propiconazole	26.8a	18.1c	94.8a
triadimefon	34.2a	43.9a	138.7a
RH 3866	31.7a	29.9b	124.6a

Figures in the same column followed by the same letter do not differ significantly at P = 0.05.

TABLE 3

Effects of November-applied fungicides on plant biomass, disease and green leaf areas in spring

#Fungicide treatment applied GS 25	February(GS 26) d.m./plant (g)	LEAF 2 GLA %	LEAF 2 DLA %	March(GS 30) d.m./plant (g)	LEAF 2 GLA %	LEAF 2 DLA %
unsprayed	0.51	62	24	0.82	48	52
fenpropimorph	0.75*	93**	6**	1.43*	67*	29*
prochloraz	0.70	84**	15	1.05*	81**	16**
propiconazole	0.67	88**	10**	1.24*	87**	10**
triadimefon	0.80*	91**	8**	1.28*	85**	10**
RH 3866	0.81*	91**	8**	1.41*	86**	8**

All November treatments were followed by prochloraz (GS 31) + propiconazole (GS 39).
GLA - green leaf area; DLA disease leaf area (back transformed means).
Significantly different from unsprayed at * P = 0.05; ** P = 0.01.
Fungicide treatments did not differ significantly from each other.

By mid-March disease had increased on unsprayed plots to 52% of the area of leaf 2, however, all November-applied fungicides prolonged green leaf areas and decreased disease (Table 3).

In February (GS 26) and March (GS 30), plant dry matter production was greater (24 - 78%) on plots that received November fungicides than on those that did not (Table 3). However, no significant yield increase was obtained from the November-applied fungicides when followed by prochloraz (GS 31) + propiconazole (GS 39) compared with the 2-spring sprays alone.

Spring-applied fungicides

Two days after spraying in the spring (3.4.84.) (GS 31) most fungicides decreased mildew inoculum; 7 and 14 days after spraying all nine fungicide treatments substantially decreased the number of mildew conidia caught (Table 4). The greatest reduction on each occasion was obtained with the experimental mixture fenpropimorph plus prochloraz (each at half-strength). Overall, the fungicide treatments decreased mildew spore production by between 43 and 89%.

TABLE 4

Effects of spring-applied fungicide treatments on inoculum of *E. graminis* and longevity of disease suppression

Fungicide treatment* applied GS 31	mildew spores caught/l days post GS 31 spray				period (d) between GS 39 spray and detection of new lesions	
	7d	14d	Total	Red.%	powdery mildew	leaf blotch
unsprayed	75.3a	24.2a	135.4	-	7	7
prochloraz	36.5c	4.6c	53.7	60	31	31
propiconazole	12.4d	3.8c	43.3	68	24	16
pyrazophos	5.4e	12.6b	28.4	79	31	7
RH 3866	56.9b	13.6b	77.6	43	16	7
fenpropimorph and chlorothalonil	2.8ef	1.3cd	36.1	73	31	31
fenpropimorph and iprodione	2.9ef	1.1cd	29.7	78	31	16
fenpropimorph and prochloraz	1.3f	0.70d	15.5	89	31	31
triadimenol and prochloraz	9.9d	0.72d	33.4	75	31	31
triadimenol and propiconazole	13.8d	2.2c	38.0	72	24	24

Figures in the same column followed by the same letter do not differ significantly at P = 0.05.

*No fungicide applied in autumn.

During late spring leaf blotch in addition to powdery mildew, increased markedly on unsprayed plots. Data from the 'labelled tiller' assessment showed that mildew was fully suppressed for at least 3 weeks by all fungicides except RH 3866 (Table 4). Control of leaf blotch, was relatively short-lived with pyrazaphos or RH 3866, whereas prochloraz, fenpropimorph + chlorothalonil and triadimenol + prochloraz fully suppressed this disease for at least 4 weeks.

By mid-June (GS 75), 28 days after the GS 39 sprays, propiconazole, fenpropimorph + chlorothalonil, fenpropimorph + prochloraz and the experimental mixtures containing triadimenol each had prolonged the duration of green leaf areas and decreased disease areas, more so than all other spring-applied fungicides (Table 5).

TABLE 5

Effect of spring-applied (GS 31 + GS 39) fungicide treatments on disease, green leaf areas and on yield

Fungicide treatments applied at GS 31 and GS 39	Leaf 2 - 28 days after spray at GS 31		GS 39		Grain yield
	GLA %	DLA %	GLA %	DLA %	t/ha
Nil (unsprayed)	92a	8a	26a	36a	8.79
prochloraz	92a	7a	76ab	20ab	9.56
propiconazole	96a	4a	95b	4b	9.80
pyrazophos	93a	7a	71ab	16ab	9.52
RH 3866	96a	4a	37ab	17ab	9.30
fenpropimorph and chlorothalonil	94a	6a	98b	1c	9.76
fenpropimorph and iprodione	98b	2b	78ab	17ab	9.89
fenpropimorph and prochloraz	95a	4a	96b	3b	9.84
triadimenol and prochloraz	97a	3a	96b	3b	9.95
triadimenol and propiconazole	96a	3a	97b	2b	10.02
prochloraz (GS 31) followed by propiconazole (GS 39)	93a	7a	84ab	12ab	9.68
LSD	-	-	-	-	0.50

Figures in the same column followed by the same letter do not differ significantly at $\underline{P}$ = 0.05.

With the exception of RH 3866, all spring-applied fungicide treatments significantly increased yield compared to unsprayed. There were no significant yield differences between treatments (Table 5). The highest yield figure (10.02 t/ha - a 14% increase compared with unsprayed) was provided by GS 31 and GS 39 application of the experimental mixture triadimenol and propiconazole (Table 5).

DISCUSSION

There is some diversity of opinion regarding the value of autumn sprays on winter barley; yield responses are rather variable and in many cases unpredictable (Stevens & Yarham 1981). In this experiment, mildew in autumn exceeded the amount suggested by ADAS as necessitating treatment and autumn fungicides gave good disease control and increased plant biomass. However, no yield benefit was obtained from autumn sprays. One hypothesis might be that the greatly increased plant biomass - more leaf and stem tissue - on autumn-sprayed plots may have provided a greater surface area for water loss through transpiration, thereby increasing environmental stress and impairing grain filling.

All fungicide treatments applied twice in the spring gave good control of powdery mildew and leaf blotch, the most prevalent diseases, and improved yield compared with unsprayed. Encouragingly the experimental fungicide mixtures gave disease control consistent with that from glasshouse evaluation (Jordan & Best 1984, 1985 in press). In some cases there were advantages in disease control from mixtures over single fungicides; the presence of a morpholine, fenpropimorph, in experimental mixtures gave better mildew control than mixtures of two triazoles, but this was not reflected in yield response.

These mixtures, and selection of components and rates, need further appraisal in sites and seasons where net blotch, leaf blotch and brown rust are more prevalent and their effects on shifts in sensitivity of pathogen populations studied.

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SEED TREATMENTS FOR CONTROLLING SLUGS IN WINTER WHEAT

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ABSTRACT

In laboratory tests on seed treatments to control slugs (Deroceras reticulatum) in winter wheat, the treatments most effective in preventing damage to the seeds were: aldicarb, thiocarboxime, methiocarb, ioxynil, bromoxynil, dinoseb, nereistoxin, cartap hydrochloride, thiocyclam hydrogen oxalate, geraniol and avermectin B_1. Some materials were phytotoxic, including thiocyclam hydrogen oxalate. However, polymeric salts of thiocyclam did not affect germination, and were still effective in preventing feeding by slugs. In a field trial at a site with a high population of slugs, methiocarb, cartap hydrochloride and thiocyclam polystyrenehydrosulphonate seed treatments were more effective than methiocarb pellets mixed with the seed. The best seed treatment, methiocarb at 0.1% a.i./wt of seed, increased yield by 50% compared with untreated controls.

INTRODUCTION

Slugs damage winter wheat by hollowing newly-sown seed, by severing shoots below ground and by shredding the leaves. Seed hollowing is the most important form of damage as it prevents germination. It is caused by surface-dwelling slugs (mainly Deroceras reticulatum) which are favoured by substantial debris on the soil surface arising from oilseed rape crops and unburnt straw, and by agricultural practices such as direct drilling associated with minimum cultivations.

Current methods of control rely on pelleted baits containing metaldehyde or methiocarb either broadcast or mixed with the seed. However, when slug populations are high and conditions favour activity, pellets are unreliable and re-drilling may be necessary. New methods of chemical control are being investigated including the use of repellent or molluscicidal seed treatments. Laboratory and field tests of seed treatments against slugs have been reported previously by Gould (1962), Symonds (1975) and Scott (1977 and 1981). This paper describes further laboratory tests of new compounds and evaluation of the most effective materials in a field trial.

MATERIALS AND METHODS

Laboratory Tests

Compounds selected from commercially available pesticides, chemicals known to be repellent to other organisms and chemicals derived from natural products, were tested in the laboratory for their effectiveness in killing slugs (D. reticulatum) and/or preventing slug damage to winter wheat seeds. Promising materials were also tested for effects on germination of seed. The test methods were described by Scott et al., (1977). Most materials were stuck to seeds at 0.2% a.i./wt. of seed by mixing in a beaker with 3% methyl cellulose. Exceptions were avermectin B_1 (0.4%)

suspension and microencapsulated thiocyclam (4% slurry) which were applied from a spinning disc to seeds in a small Rotostat machine to give 0.02% and 0.2% a.i./wt of seed respectively. Technical thiocyclam hydrogen oxalate was used to prepare the microencapsulated material at Rothamsted, the capsules had polyurea walls and measured 1-5 μ in diamter. Chemicals not identified by common names in the tables are:-

CGA 73102 an experimental carbamate
PP-99 (Kumiai Chemical Industry Co. Ltd.)
2,6-Dibromo-4-(4-nitrophenylazo) phenol
TI 78 an experimental compound related to nereistoxin
UNI K 840 5-dimethylcarbamoyl-4-methyl-2-(3-pyridinyl)-thiazole
A 5160 2-(3,4-dimethylanilino)-2-oxazoline
thiocyclam compound I thiocyclam hydroalginate
thiocyclam compound II thiocyclam polystyrenehydrosulphonate

The thiocyclam compounds have been developed at Rothamsted and are polymeric salts of the thiocyclam base and alginic acid (thiocyclam compound I) or polystyrenesulphonic acid (thiocyclam compound II).

Preparation of polymeric salts of thiocyclam

Thiocyclam hydrogen oxalate (1g) was stirred in water and 2M KOH solution added until just alkaline to phenolphthalein. The milky precipitate was extracted into ether which was washed with water. Either alginic acid (4g) or polystyrenesulphonic acid [Dowex 50W x 8(H)] (5g) was added as an aqueous slurry and the water and ether then removed using a rotary film evaporator to give a dry powder (c. 5g).

Field test

Three materials which protected seeds from damage by slugs in the laboratory tests and were not phytotoxic, were tested in 19 field experiments in collaboration with 9 ADAS Regions; a full account will be published elsewhere. In many of the trials, slugs were not active enough to cause significant damage, but a summary of one where slug damage was severe, is given here. Winter wheat seed was treated at Rothamsted in a mini Rotostat using a methyl cellulose sticker and commercial formulations of methiocarb (Bayer 5024 50% powder) and cartap hydrochloride (Padan 50% powder). Thiocyclam compound II was prepared from a 12% powder and control seed was treated with talc. Seed treatments were compared with a commercial formulation of 4% methiocarb pellets ("Draza") mixed with the seed before drilling at a rate equivalent to 5.5 kg pellets/ha. The seed was direct drilled on 4 November 1982 at a site in Graveney, Kent, following oilseed rape. It was not possible to calibrate the seed drill for each treatment; flow rates were, nevertheless, similar and the numbers of seeds recovered from soil samples after drilling were not significantly different between treatments. The treatments were replicated four times in a randomised block design. Slug activity measured in October averaged 27 slugs/trap/week. Soil samples taken in December after brairding were washed through sieves and the seeds examined for slug damage. Grain yields were taken at harvest.

RESULTS

Laboratory Tests

The effects of treatments on survival of slugs and damage to seeds are summarised in Tables 1 and 2. The pesticides aldicarb, thiocarboxime, methiocarb, ioxynil octanoate and PP99 were the most toxic to slugs (<60%

live slugs compared with controls on day 10). Moderately toxic treatments were quinalphos, dinitrophenol, nereistoxin and thiram (<70% live slugs). None of the repellent or natural products was toxic. Only aldicarb and geraniol protected seeds completely from slug damage, but thiocarboxime, dinoseb, ioxynil and bromoxynil were very effective (<30% seeds damaged compared with controls). Methiocarb, avermectin B_1 and the compounds related to nereistoxin, with the exception of microencapsulated thiocyclam and TI 78, were moderately effective (<50% seeds damaged).

TABLE 1

Laboratory tests of seed treatments against slugs: Pesticides

Pesticide Class	Name	Numbers (as % of controls) of Live slugs Day 3	 Day 10	 Damaged seeds Day 3	 Day 10
Carbamate	aldicarb	20	11	0	0
and organo-	carbofuran	100	100	50	100
phosphorus	CGA 73102	90	70	33	90
insecticides	cloethocarb	100	90	100	100
	methiocarb	89	56	25	44
	*thiocarboxime	26	22	0	10
	quinalphos	80	67	0	67
	temephos	100	100	100	125
Phenols	*ioxynil	100	103	0	28
	ioxynil octanoate	78	57	50	63
	bromoxynil	100	80	0	20
	bromoxynil octanoate	100	100	50	100
	benzyl choline iodide	100	110	113	100
	dichlorohydroxybenzoic acid	100	100	67	90
	dinitrophenol	100	67	14	56
	*dinoseb	100	103	3	10
	PP 99	89	57	67	67
Nereistoxins	*cartap hydrochloride	95	98	9	39
	nereistoxin	100	60	0	40
	*thiocyclam hydrogen oxalate	95	95	0	33
	thiocyclam compound I	90	100	0	30
	thiocyclam compound II	100	89	13	30
	thiocyclam, microencapsulated	100	111	63	90
	T1 78	90	100	33	56
Other	amitraz	100	100	100	100
pesticides	avermectin B_1	100	111	38	50
	dazomet	100	100	56	100
	deltamethrin	100	111	100	100
	ledermycin	100	100	40	113
	morantel	90	86	100	83
	thiram	100	67	67	80
	trifenmorph	100	100	129	111
	UNI K 840	100	90	100	100

* means of 4 experiments

TABLE 2

Laboratory tests of seed treatments against slugs: Repellent chemicals and chemicals derived from natural products

Name	Numbers (as % of controls) of Live slugs Day 3	Live slugs Day 10	Damaged seeds Day 3	Damaged seeds Day 1
acetazolamide	100	90	133	100
acetylcholine iodide	100	90	67	100
anthraquinone	100	100	44	90
atropine	100	100	78	90
bitrex	100	78	89	80
cycloheximide	100	100	56	100
geraniol	100	100	0	0
magnesium iso α acids	100	89	89	80
A5160	90	140	83	56
nicotine	100	100	100	100
oleoresin of Capsicum sp.	100	100	100	100
(-)-polygodial	100	100	71	89
rotenone	90	120	83	67
undecan-2-one	100	111	111	100

Table 3 shows the effects on germination of some of the treatments which were active against slugs. Ioxynil, bromoxynil and TI 78 suppressed germination by more than 50% compared with untreated seed. Thiocyclam hydrogen oxalate also decreased germination but the polymeric forms of thiocyclam, particularly compound II, and methiocarb produced little or no phytotoxic effects.

TABLE 3

Germination tests

Treatment	Number of seeds germinated, as % of control: sand test 8 days	compost test 8 days	compost test 14 days
ioxynil	33	7	46
bromoxynil	25	7	48
methiocarb	93	96	110
cartap hydrocoride	70	85	88
TI 78	-	19	21
thiocyclam hydrogen oxalate	66	75	83
thiocyclam compound I	81	96	96
thiocyclam compound II	98	76	98

Field trial

The results are summarised in Table 4; methiocarb and cartap hydrochloride seed treatments considerably decreased grain hollowing. Except for methiocarb at 0.2% (where one plot had an unusually low yield) all seed treatments gave significantly higher yields than the control. The best treatment, methiocarb at 0.1% a.i./wt of seed, increased yield by 50% compared with untreated seed.

TABLE 4

Field test of seed treatments against slugs

Treatment	Rate % a.i./ wt of seed	% seeds hollowed	grain yield t/ha
methiocarb	0.2	7	5.7
	0.1	12	7.4
cartap hydrochloride	0.2	15	6.7
	0.1	17	7.0
thiocyclam compound II	0.2	28	6.2
methiocarb pellets (seed mix)		34	5.9
control		44	4.9

DISCUSSION

Seed treatment places the chemical where it is needed to control slugs and so should be more effective and less injurious to other soil organisms than a pelleted toxic bait. Also, a seed treatment would be more convenient and cheaper. Further requirements that must be met (Griffiths, 1978) are relative safety (a) to mammals (so that it presents little hazard during treatment, handling and sowing), (b) to birds that might eat grain, and (c) to the germinating seed. Of the materials which killed slugs in the laboratory tests, aldicarb and thiocarboxime are too toxic to other organisms to justify further development. The phenolic herbicides were very effective in preventing seed hollowing but depressed germination. Of the compounds related to nereistoxin tested in the laboratory, cartap hydrochloride and thiocyclam hydrogen oxalate prevented hollowing. The phytotoxic effect of the latter was solved by polymerising thiccyclam.

The compounds selected for field evaluation satisfied two of the desired characteristics, i.e. they killed slugs or prevented them from feeding, and had little effect on germination. The results of the trial at Graveney have demonstrated for the first time that a seed treatment gainst slugs in winter wheat can be extremely effective. However, these particular compounds are considered too toxic to birds and other vertebrates to warrant commercial development.

Promising new leads from plant extracts and their derivatives are now being investigated; a number of very effective slug repellents such as geraniol (Table 2) and molluscicides have been identified, but further laboratory studies are required before they can be tested in the field.

ACKNOWLEDGEMENTS

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SLUGS AND STRAW DISPOSAL IN WINTER WHEAT

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ABSTRACT

Measurements from 1982-84, in winter wheat grown on heavy clay soil, show considerably greater slug numbers and damage when straw was not burnt, than after burning. The three species of slugs found showed considerable fluctuations in numbers, with no species consistently predominant. Shallow cultivation (to 5 or 10 cm) to incorporate straw had little effect on slug numbers but did reduce damage compared to direct-drilled areas. Slug pellets had little effect on the high populations of slugs present on plots with straw residues, and did not significantly reduce damage to seeds and seedlings, whereas methiocarb-dressed seed did.

INTRODUCTION

This paper describes the early stages of a continuing investigation into the effects of straw disposal on slug numbers and damage in winter wheat on heavy clay soils. Slugs are often troublesome pests in winter wheat grown on soils of this type (Gould 1961), which are particularly suited to this crop and represent 45% of the cereal growing area in England and Wales (Cannell *et al.* 1982). As restrictions on straw burning increase (Cannell 1984) so also does the need to assess the consequences of this on slug populations and damage. Runham & Hunter (1970, p. 146) noted that incorporation of chopped cereal straw into heavy soils may result in increased slug damage.

MATERIALS AND METHODS

Field site

In a long-term experiment started in 1979 at the Northfield site of the AFRC Letcombe Laboratory in the Vale of the White Horse, Oxfordshire, there are four straw disposal treatments, each replicated four times in a Latin Square: (1) straw residues burnt *in situ*, (2) cut straw baled and only stubble left, (3) and (4) all straw left either chopped and spread by a combine-mounted chopper, or unchopped. Each plot was sub-divided into a direct-drilled area and areas drilled after shallow tillage to 5 or 10 cm deep.

Sampling methods

Slug numbers were estimated at intervals (usually monthly) from October 1982 onwards, using a modification of the flooding procedure described by South (1964) and Hunter (1968). Two soil samples 25 cm x 25 cm square x 10 cm deep were dug in each subplot, and placed immediately in plastic tubs with drainage holes near the base, covered with wooden lids and transported to a soil-flooding unit in which a steadily rising water level forced slugs to come to the surface over an 8-10 day period. Samples were examined daily and all slugs removed.

Damage to seeds and seedlings was estimated at growth stage 10, by hand-sorting soil from four 25 cm lengths of drill row per subplot for signs of grain hollowing and damage to shoots and roots.

Molluscicide treatments

Metaldehyde pellets (Doff mini pellets, 6% a.i.) were broadcast (16 kg/ha) on 25 October 1982, methiocarb pellets (Draza) were drilled (4.4 kg/ha) with the seed on 28 September 1983 and broadcast (5.6 kg/ha) on 31 October 1983. It was not possible to leave untreated areas when pellets were broadcast, but when pellets were drilled with the seed, a strip in the direct-drilled area of each plot was sown without pellets. Part of this strip was sown with methiocarb-dressed seed (Scott et al. 1984), and the remainder with untreated seed.

RESULTS

Slug numbers

Soil samples taken from 10 to 20 cm deep in winter and summer yielded few slugs, so samples were routinely taken to a depth of 10 cm only. On plots where straw was burnt after harvest, consistently few slugs have been found ($< 14/m^2$), whereas on plots with straw residues, slug numbers were consistently greater, with a mean number as high as $180/m^2$ (Fig. 1a). There were no consistent differences between slug numbers on plots with entire straw residues and those with stubble only.

Three species of slug were commonly found (Fig. 1b), the netted or grey field slug *Deroceras reticulatum*, the silver slug *Arion silvaticus* and the hedgehog slug *Arion intermedius*. The numbers of all species fluctuated considerably, with none predominant (Fig. 1). Slugs of all species were abundant throughout the wet period from October 1982 to June 1983, but few were found in the hot, dry conditions of July and August 1983. Probably many had migrated deep into the soil using the large cracks that appeared in the dry soil, because numbers of both *Arion* spp. recovered rapidly in autumn 1983 with the onset of cooler, wetter weather. However, numbers of *D. reticulatum* did not recover to the same extent. Treatment of the experimental area with molluscicide pellets had little apparent effect on slug numbers (Fig. 1). However, the methiocarb pellets broadcast on 31 October 1983 may have contributed to the marked decline in *A. silvaticus* numbers after that date.

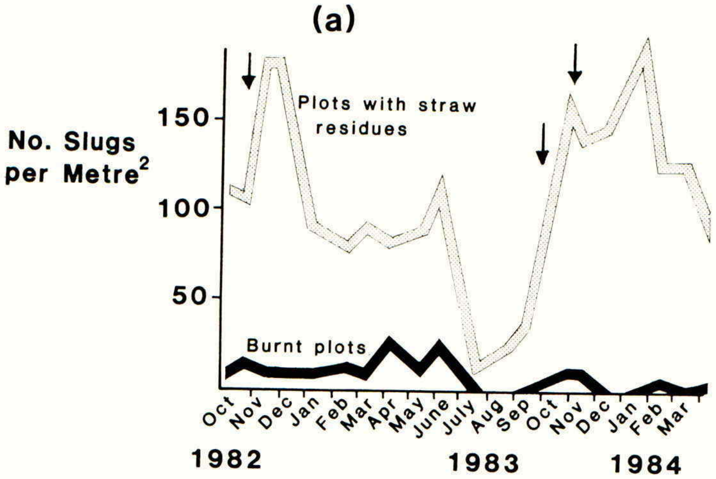
Cultivation to incorporate straw to depths of 5 or 10 cm had no immediate effect on slug numbers (Table 1) and appeared to have little

TABLE 1

Numbers of slugs on zero-tillage compared with shallow cultivated areas of plots with straw residues

	Slugs/m^{2*}	
Cultivation*	Straw chopped and spread	Straw unchopped
Zero tillage	16#	56
Tilled to 5 cm	50	44
Tilled to 10 cm	32	76#

*Plots were harvested on 8 August, tilled on 13 August and sampled for slugs on 14 September 1983.
#Only the smallest and largest values are significantly different (*P* = 0.05).



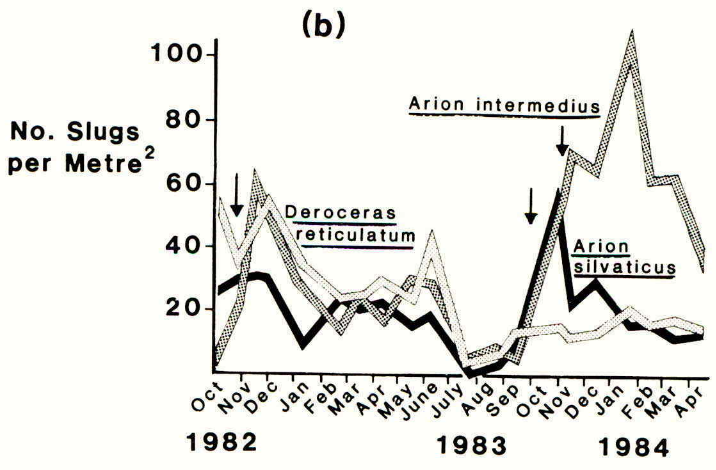


Fig. 1. Slug numbers in the top 10 cm of soil on direct-drilled winter wheat at Northfield, Oxfordshire; (a) all species of slugs on burnt plots compared with those with straw residues (b) each species of slug on all plots. Arrows indicate the dates of molluscicide treatments.

effect in general except that, in the relatively dry conditions of late autumn-early winter 1983, subplots with incorporated straw had fewer slugs than direct-drilled areas; possibly drier soil in the incorporated areas made conditions less favourable for slugs than direct drilling.

Slug damage

Damage to seeds and seedlings was severe on direct-drilled areas with straw residues in both autumn 1982 and 1983 (Table 2). This damage was patchy, with large areas almost bare, and was worst where straw was chopped and spread. In contrast, only c. 5% damage occurred on burnt areas. Methiocarb pellets drilled with seed in autumn 1983 did not significantly reduce damage whereas methiocarb seed dressing did (Table 2). On subplots where straw was incorporated, damage was not recorded in 1982, but in autumn 1983 damage was substantially less than on direct-drilled areas (Table 2).

DISCUSSION

These results show that the risk of crop damage increases if straw residues are left in fields. Stubble itself encourages slug populations. It is not known how long slugs took to reach such damaging numbers at Northfield because sampling started three years after the beginning of the experiment. However a nearby one-year straw-incorporation experiment on similar soil at the Compton Beauchamp site of the AFRC Letcombe Laboratory revealed few slugs. This illustrates the need for long-term experiments on straw disposal to show the extent of pest problems.

The survival of large numbers of slugs after treatment with metaldehyde or methiocarb pellets (Fig. 1) and the severe damage to seeds when drilled with pellets (Table 2) contrasts with the greater and more lasting effect of burning in controlling slug numbers and damage. Pellets baited with molluscicide are likely to be more effective when slugs are less numerous.

Whilst shallow incorporation of straw did not reduce slug populations, it did result in a significant reduction in damage to seeds and seedlings compared to direct-drilled plots. Presumably cultivation to incorporate straw made the seeds less accessible to slugs. Work is planned on the effects of incorporation of straw residues, with and without molluscicide treatment, on slug numbers and damage.

The yields recorded in this experiment in past years (Cannell et al. 1982, Christian & Miller 1983) show a pattern consistent with the levels of slug damage reported here, i.e. highest yields on burnt plots, intermediate on plots with shallow incorporated straw and lowest yields on direct-drilled areas with straw residues. However, more work is needed to distinguish the effects of slug damage on yield from other factors including impedance of the drill mechanism by straw (Lynch et al. 1981), toxin production by decomposing straw (Lynch et al. 1980) and effects of pathogens such as Cephalosporium leaf stripe (Christian & Miller 1984).

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TABLE 2

The effects of straw disposal, cultivation, slug pellets drilled with seed and seed dressing on the percentage of winter wheat seeds and seedlings killed by slugs

Sowing date	Cultivation	Molluscicide treatment	% seeds and seedlings killed by slugs				L.S.D.
			Straw burnt	Straw baled stubble left	Straw chopped and spread	Straw unchopped, removed to drill and replaced	
12/10/82	Direct-drilled	Untreated	5.9	31.4	46.8	24.9	18.8
28/9/83	Direct-drilled	Untreated	6.8	29.3	34.0		
	Direct-drilled	+ methiocarb pellets	5.1	21.5	38.3		
	Direct-drilled	Methiocarb seed dressing	3.5	8.1	6.8		12.2
	5 cm tillage	+ methiocarb pellets	4.1	12.5	9.7		
	10 cm tillage	+ methiocarb pellets	4.6	4.3	13.5		

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CEREAL DISEASE CONTROL, CURRENT POSITION AND FUTURE TRENDS

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SUMMARY

Within the last decade changes in economics, farming systems, weather patterns and new fungicides have dramatically increased our perception of cereal diseases and the need for their control. The result has been a series of evolving problems for the plant breeders, the growers, the advisers and the chemical industry. Changes at this speed have not been usual in agricultural industry, but the success in accepting new approaches is reflected in the record cereal yields achieved in the 1984 season over a wide area of Europe. In some respects changes in cereal production continue to occur too quickly. In continuing to use yet more sophisticated techniques it is time to reflect on whether we should continue to introduce new concepts at the same rate or consolidate on some of our better ones.

INTRODUCTION

Plant breeders have made enormous contributions to the present status of cereals in Western Europe. Introduction of good winter barley varieties, short strawed wheats and improved disease resistant varieties have, in some cases, led to yield potentials in excess of earlier expectations. Wheat varieties which allow the use of high fertilizer inputs and benefit from pest and disease control are increasingly seen to give yields of 10 tonnes/ha. However, the UK national average of 6 tonnes/ha reminds us that we still have room for improvement if we are to make full use of the potentials made available by the breeders.

There has been a change in emphasis in the UK from spring to winter barley and the increased proportion of land sown to winter wheat. In five years the area of wheat grown in the UK has doubled to 1.8 M ha and the same change is recorded for winter barley at 0.9 M ha in 1984. Spring barley at just over 1 M ha in 1984 has declined in area in recent years.One benefit is that it enables the grower to complete most of his sowing early in Autumn. Much of the work is completed before end of September and it is not unusual to see well established crops at the end of the month. As a consequence 'green bridges' for disease carryover have become common. The increasing use of minimum cultivation techniques or reduced stubble burning and varieties not renowned for disease resistance characteristics, augment the disease risk situation. These combinations give ideal platform for earlier and more damaging disease potentials in our crops.

Varieties grown in the U.K. in 1984 utilize much of the disease resistance potential available. There are notable exceptions in the UK and in other European countries. Golden Promise barley in Scotland and Kanzler wheat in Germany are examples which have significant deficiencies in respect of resistance to mildew.

Fungicide inputs to the cereal crops show a remarkable growth pattern during the last decade. For example in France over that period the fungicide market has grown from nothing to its present £100 million pound value. In the UK in 1984 6.8 chemical spray hectares were applied. This represented an increase of 6.5% over 1983 but falls well short of the 20 and 30% increases seen in other years. It reflects the lower disease pressures recorded and requiring treatment. Expressed as applications to the crop, in 1984 the average winter wheat field received 2.5 sprays, the winter barley crop 1.8 sprays and spring barleys 1.2 sprays. Looked at another way 90% of the winter crops received an application of fungicide whilst 60% of the spring crop received at least one spray. Whilst France and the UK represent examples of well developed cereal fungicide markets other countries including W. Germany, Denmark, Holland and more recently N. America have sizeable markets.

PRESENT DISEASE PATTERNS

Seed Treatments

Good systemic materials including triadimenol and carboxin have now largely replaced mercury based products. Whilst controlling the traditional seed borne problems they have the advantage of also controlling some foliar diseases, including mildews. In addition there are increasing claims that Take All, (*Guaemannomyces graminis*) can also be suppressed in the high risk situations following seed treatment with triadimenol + fuberidazole. Whether the increasing levels of Septoria spp. and Net Blotch on wheat and barley reflect less adequate control of the seed borne infections than previously seen with mercury products has never been proven.

Foot Rot Diseases

Pseudocercosporella herpotrichoides has been recognised as a significant problem in winter wheat for a number of years. More recently the extent and damage of the disease on winter barley has increased and control measures are widely practised. Our understanding of eyespot needs to be refined if we are to make the best use of our control materials. In general the recommendation for sprays on wheat are for an application at growth stage 32. On barley equally good responses may be achieved with later sprays.

Growers in the UK are advised to spray when 15-20% infection is recorded. In some years this may well be too late since we know that symptom expression does not always correlate with infection periods. The result can often be variable levels of disease control when assessed at the conventional time, together with variable yield responses. There is a need to understand more fully the epidemiology of the eyespot disease.

In the South West parts of the UK early drilling followed by appropriate conditions give rise to high infection levels which may be well established and damaging long before growth stage 32. Under these conditions it is not surprising that disease control from carbendazim or prochloraz is not as high as we would wish. Attempts to control a well established eyespot population also gives rise to a strong selection pressure and probably accounts for the speed at which resistance to carbendazim has built up in different areas. Regional variation in the behaviour of the eyespot fungus must be the key to improved disease control through chemicals. The similarities between the wheat areas of the Pacific North West of the USA, much of the UK, Denmark, N. France and N. Germany suggest that patterns do occur and should be quantifiable.

Whilst much of our interest centres on eyespot, other foot diseases should not be ignored. Sharp eyespot cause by Rhizoctonia cerealis has steadily increased in recent years and is now considered to be damaging with stem infections causing yield loss. Reliable control is not yet possible although clearly there are materials which in theory should be capable of controlling the disease. Again we are short on the epidemiological knowledge which would allow a more relevant application schedule to be adopted.

Fusarium foot rots are also common and their significance is probably underestimated. Our own studies in recovering eyespot from tissues reveal high levels of Fusarium present, especially late in the season. We also know that as in Germany many of the Fusarium isolates are resistant to MBC. (Radtke, 1983).

Studies in Germany (Reinecke et al) and more recently in the UK have demonstrated that interaction between the various foot rots are important causes of plant failure or reduced vigour.

Foliar diseases

The importance of the various foliar disease can vary widely. On winter wheat, mildew Erysiphe graminis is rarely a problem in France and the UK. In contrast disease levels have been high in Germany in the last two years. The problems seen in Germany are in part caused by the use of mildew susceptible varieties. In the UK and Germany rust diseases on wheat tend to be sporadic but can be devastating when they occur, especially yellow rust Puccinia striiformis. Brown rust is clearly more damaging as one travels south. Area of South West France regularly suffer severe attacks with severe yield loss if not controlled.

Septoria spp. on wheat continues to cause problems both in recognition and control. There has been a general increase in levels of Septoria recently with S. tritici being seen on the upper parts of the plant. A number of products can give good control, although on a number of occasions persistence may be a limiting factor.

On the Winter barley crops net blotch (Pyrenophora teres), leaf blotch (Rhynchosporium secalis) and mildew (E. graminis) are the major problems although the control of Brown Rust is necessary on many occasions. In the winter crop it is common to see high levels of Net Blotch in the autumn and to maintain plant numbers and good establishment treatment at that time can be justified but must be supported with spring applications.

From everyones point of view the control of diseases on the foliage present problems. The grower wants clear advice on what and when to spray, the advisers need to keep two steps ahead of the diseases in order to give the grower the chance to make his applications at the correct time, and the manufacturers and trade have to be in a position to provide material for a number of possibilities. To meet the latter there has been an increasing trend towards broadening the spectrum of products either by co-formulation or tank mix recommendations. Prochloraz and propiconazole have the broadest spectrum but throughout Europe there are many combination products available.

Ear Diseases

Traditionally late season sprays made to wheat were made at ear emergence with the aim of keeping both flag leaf and ear, disease free. Increasingly this spray is made at flag leaf emergence because of disease present on the lower foliage. Unless followed up by a later application, the grain quality may be at risk from the ear disease complex of *Fusarium*, *Septoria*, mildew, and the various sooty moulds which were commonly seen this year. The applications made at this time require broad spectrum products with good persistency.

FUTURE TRENDS

There is a danger when making a prediction of future trends that criteria are based on previous experience. As outlined in the introduction many rapid changes have occurred as the economic climate has encouraged intensive production. This climate is unlikely to continue. The pressure will come for increasingly cost effective disease control in which fungicides will continue to play a major role.

New Diseases

We are likely to see new disease, as those which are currently causing yield losses are more effectively controlled. Where narrow spectrum materials are regularly used the emergence of new problems will be quite rapid. *Typhula* may be expected to increase in some Northern areas of Europe especially if autumn applications are made using materials which do not control the pathogen. *Rhizoctonia* is already being seen as a threat to the stem base. Diseases such as *Ascochyta* are often recorded but do not cause serious damage.

Virus problems will be seen as more significant in the future. Barley Yellow Dwarf Virus control measures are being improved through vector control. Although at present not thought to be serious in the UK, Yellow Dwarf Mosaic Virus has increased in Europe and in France is causing major concern in the winter barley growing areas. Transmitted by the soil fungus *Polymyxa graminis* infection, symptom expression and damage are mediated by weather conditions. Whether effective control can be achieved by soil fungicide applications remains to be seen.

I anticipate an increasing interest in the control of soil diseases affecting cereals. Full yield potential is unlikely to be reached until the soil pathogens including Take All are recognised, understood, and controlled. Fungicides will have a role to play but 'beneficial' organisms will need to be recognised and retained. Soil borne *R. solani* is a component of root disease in many countries. Apart from the 'bare' patch effect recorded over many years it is clear that the disease can have less than lethal effects on the plant (Moen and Harris). It would be surprising if other root attacking organisms in addition to Take All were not causing root damage. Studies by Jenkins on continuous wheat crops which included soil sterilisation suggested that *Pythium* was implicated. As always in soil studies the knowledge will be slow to accumulate.

New Varieties

The rapid introduction of new varieties and the subsequent displacement of previously popular varieties means a constant reappraisal of a fungicide's performance. This variety/fungicide interaction will play an increasingly important role as production cost factors have to be reduced. The judicious alternation of variety and fungicides may well safeguard the considerable expense involved in their production by reducing the risk of varietal disease resistance failure and the appearance of pathogen races resistant to the chemical.

The introduction of the varietal diversification scheme (NIAB) offers a strategie to reduce risk of some diseases. Whilst initially the concept will add to the complexities for the grower the ultimate benefits justify perseverance. The problems of mildew infections on the large areas of Kanzler and related wheat varieties (Frahm) are testimony to the folly of growing varieties of limited disease resistance.

Fungicides

Currently there are good chemicals available for controlling the major recognised diseases. The recently described problems associated with resistance in the eyespot fungus to the MBC fungicides (Yarham & Griffin) highlights one of the risks associated with the use of a single active ingredient against a target organism over a number of years. If we are to retain products for a satisfactory period of years it will be necessary to adopt strategies to delay the onset of resistance and its progression. Unfortunately the information necessary to evolve strategies takes times to acculmulate, time during which the first changes may be taking place within the fungal population. Caution is also required when generalising in statements on cross resistance. It is now apparent that before we can state categorically that cross resistance occurs between related molecules we must be sure that the effect of each chemical is the same on all aspects of the pathogen's life cycle or fitness (Buchenauer). Germination, vegetative growth, sporulation, response to environment are just some of the parameters involved.

We can expect to see continuing use of a broad spectrum approach to foliar disease control. In the short term the need will be met by tank mixes and co-formulations. The cost benefits of such mixtures will come under closer scrutiny as grain prices move downwards.

I would also expect to see a re-appraisal of our attitude to the balance between the cosmetic effect and the cost benefit of fungicide applications. There has been a progressive improvement in the efficacy of the disease control measures to the point that we have come to expect 100% control. This is true for manufacturer, for advisers and for growers. Provided these control levels are allied directly to yield responses there is some merit in this attitude. However, the growers may soon feel that he can live with something less than perfection. Should this approach appear, there will be a real need to know the economic thresholds for disease control. The modelling techniques described by Norton & Way, (1984) Royle et al (1984) and the acculmulation of the necessary facts on *Septoria* (Hoffman 1984) are examples of the approaches that will become more significant.

The introduction of legislation to lighten the UK PSPS scheme whilst applauded by all in the industry will bring with it far reaching effects. To date the trials work by the manufacturer have been used in the U.K. to support registration. Any change which means only independent information would be used in the registration process would be a retrograde step. The manufactures are in a position to acculmulate information on a broad front and evaluate the reliability of their recommendations in many areas. To largely replace this with independent organisation would be a costly exercise.

Finally, it is necessary to address how we will achieve the more sophisticated understanding of fungicide control of cereal diseases. Clearly there is a need for improved disease prediction based solely on environmental characters (Fry and Fohner, 1983) but on full agronomic, economic and social factors. Schemes are appearing and the manufactures are making useful contributions (Myram and Kelly 1981). The changing role of ADAS is causing some concern in the industry. Previously they have played an invaluable role in the extension of the manufacturers recommendations. They have had the opportunity to evaluate new products not only in comparative roles but importantly from the stand point of improved disease management programmes. It would be unfortunate if this practical co-operation were to cease.

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CEREAL PESTS: PRESENT PROBLEMS AND FUTURE PROSPECTS

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ABSTRACT

The major pests of cereals: aphids, wheat bulb fly (*Delia coarctata*) and slugs are discussed in relation to their life histories, damage potential and current control practices. Future developments in pest control are discussed in relation to possible changes in the Common Agricultural Policy and legislation regarding agricultural practices. It is suggested that the most important research areas are the development of simple monitoring methods, accurate forecasting systems and the establishment of damage thresholds.

INTRODUCTION

An account of pest control in cereals must be viewed in relation to recent developments in agriculture in the U.K. In terms of area, wheat and and barley are the predominant cereals, together occupying four million hectares (Anon. 1983), but the relative importance of these two crops has changed recently. In England, in 1978, 50% more barley than wheat was grown (Anon. 1983) but by 1983 wheat had just replaced barley as the major crop (Anon. 1984a). Since 1979, (when winter and spring barleys were first recorded separately, in the Agricultural Returns) there has been a change from spring to winter barley,which now predominates, so in England over 75% of cereals are autumn-sown. There has been a similar trend in other parts of the U.K. For example the area of wheat grown in Scotland doubled between 1978 and 1982 to over 40 000 ha, and the area of barley, the predominant cereal, showed a modest increase to over 450 000 ha, much of this presumably autumn-sown although the Agricultural Returns do not record winter and spring barley separately for Scotland (Anon. 1983).

In addition to these large-scale changes in the quantity of cereals grown, crop agronomy has also altered. Earlier sowing has become widespread, although difficult to quantify, and many farmers aim to finish drilling in September, if weather permits. This obviously shortens the period between harvest and emergence of the following crop. Fertiliser usage has increased; for example on winter wheat the average amount of nitrogen applied has risen from 145 in 1980 to 181 kg/ha in 1983 (Church 1984). An increase in the amount of nitrogen applied is likely to result in delayed leaf senescence which is advantageous to those pests occurring immediately prior to the ripening period.

Pesticide usage has changed dramatically in recent years: the area treated with insecticides and molluscicides almost doubled between 1977 and 1982, as did herbicide usage while fungicide usage increased by more than five times. As a result pesticide treatments have increased from an average of three to more than five (Sly 1984). Similar areas of cereals are treated with molluscicides and insecticides but with a total usage of just over one million spray hectares they come a poor third behind herbicides (7.4 million spray ha) and fungicides (5.2 million spray ha). In addition in 1982, insecticidal seed treatments were used on 27% of cereal seeds against wireworms (*Agriotes* spp. larvae) and 11% against wheat bulb fly (*Delia coarctata*) (Sly 1984). However, it has been suggested that the broad spectrum activity and persistence of many insecticides may have a more deleterious, longer-term, effect on the environment than herbicides and fungicides (Short 1982).

The objective of this paper is to review the current pest problems in barley and wheat and attempt predictions of future changes.

MAJOR PESTS

Aphids

Aphids cause damage to cereals by direct feeding damage, primarily a problem on wheat, and as vectors of barley yellow dwarf virus (BYDV) which infects all cereals but is a particular problem with autumn-sown crops.

The grain aphid, Sitobion avenae, is the principal species causing direct feeding damage. It is monoecious on grasses and cereals and commonly overwinters viviparously on crops although sexual forms occur in the autumn (Dewar & Carter 1984). In May and June aerial migration results in the widespread colonisation of cereals which in some years (e.g. the widespread outbreaks of 1984) is followed by rapid population growth. The aphids respond to the deteriorating conditions of the host plant, towards the end of the milky-ripe stage, by producing offspring which develop into alatae (winged forms) which migrate to grasses.

The grain aphid is a sporadic pest. Its economic threshold level is five aphids per ear, at the onset of flowering, with an increasing population (George 1975). Aphicides, such as pirimicarb, dimethoate or demeton-S-methyl, should be applied as soon as possible if this threshold is exceeded. Unfortunately many sprays are still not economically justified either because aphid densities are too low (Dewar 1983) or because they are applied too late (Watt et al. 1984).

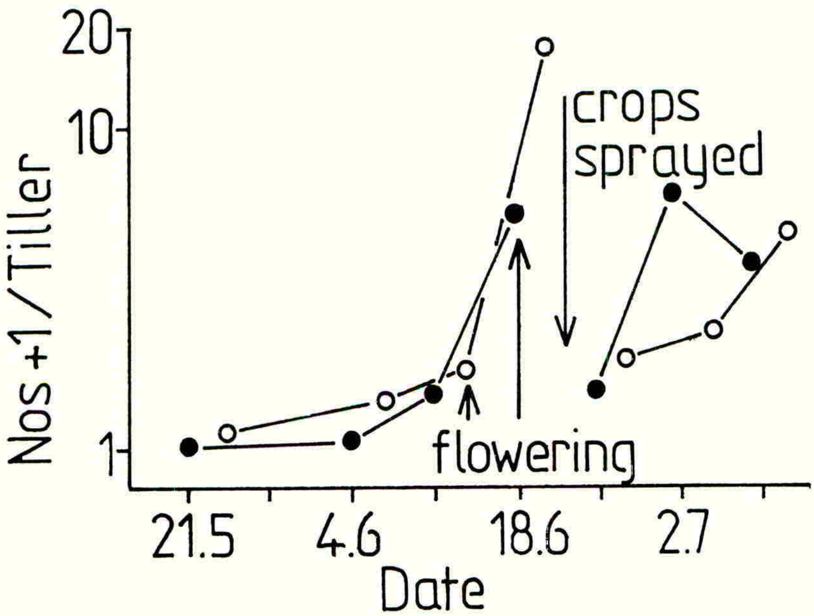

Fig. 1. The effect of sowing date (O, 19.9.83; ●, 18.10.83) on Sitobion avenae in wheat fields near Rothamsted, in 1984.

It is unlikely that the increase in the area sown with wheat has resulted in a greater risk of outbreaks of the grain aphid although in outbreak years probably more aphicide is used. Earlier sowing in the autumn results in higher densities of overwintering aphids (Dewar & Carter 1984) although in outbreak years this effect is not great enough to be of concern to the farmer (Fig. 1). The consequencies of the increase in the use of fungicides, many of which have insecticidal side-effects on natural enemies (Sotherton & Moreby 1984) have not been researched fully although the frequency of aphid outbreaks has not risen. This suggests that they have only a limited effect on the aphid-natural enemy balance. The increase in fertiliser usage similarly has not caused more frequent aphid outbreaks.

In contrast, the most important species involved in BYDV spread in the autumn is the bird-cherry aphid, Rhopalosiphum padi, although S. avenae and the rose grain aphid, Metopolophium dirhodum are also vectors (Plumb 1981) e.g. S. avenae caused problems in the north of England in the autumn of 1983. R. padi can overwinter in the egg stage on its primary host, bird-cherry, Prunus padus or viviparously on cereals and grasses. There are several strains of BYDV, which differ in their efficiency of transmission by different vector species and their severity. While the effect of sowing date on summer aphid populations remains unclear, its influence on BYDV in the autumn is definite. Earlier sowing leads to increased risk (Gair 1981). This is because the crop is exposed to migrant aphids, predominantly R. padi, for longer which allows more time for population development and virus spread to occur prior to the winter and plants are more susceptible when infected early. A measure of risk from migrant aphids is estimated using the Infectivity Index which is the summation of the products of the numbers of each cereal aphid species caught in the 12.2 m suction traps of the Rothamsted Insect Survey (Taylor 1974, Taylor et al. 1981, Woiwod et al. 1984) by the proportions of each species found to be infective (Plumb 1981). Infection may also occur, in some crops, from aphids already present which have survived the interval between harvest and crop emergence on grass weeds, cereal volunteers or ploughed-in grass leys. Earlier sowing shortens this interval which increases the risk of infection from this source.

Current ADAS recommendations integrate Infectivity Index, sowing date and presence of aphids on the crop. Crops are classified in three groups, according to sowing date; (i) before mid-September, (ii) mid- to late-September, and (iii) after September. Crops in the first group should be sprayed with a synthetic pyrethroid in mid-October if in areas where BYDV has caused significant damage in recent years or if aphids are present or if ADAS warnings indicate a high risk, perhaps due to a large Infectivity Index. The threshold for this latter criterion may vary on a regional basis and more work needs to be done to set these levels. Recommendations for control in crops in the second group are similar to the first, except the spray should be applied in late October or early November. Crops in the third group need only be sprayed, at this time, if aphids are present in the crop or if ADAS warnings indicate a high risk. In addition, preliminary trials, by ADAS, indicate that crops following grass leys can become badly infected but are safeguarded by spraying the ley with paraquat 10 days before ploughing or two weeks before drilling where minimal cultivations are used.

These recommendations are likely to result in the increase in the area of cereals sprayed in the autumn.

Slugs

Several species of slugs cause damage to cereals, especially autumn-sown crops, although the field slug, Deroceras reticulatum, is the most damaging. It has two generations a year with peak numbers occurring in April-May and September-October (Gair et al. 1978). Control is by soil applications of methiocarb or metaldehyde pellets, usually several days before drilling, and their use has risen from 29 205 and 3 011 hectares in 1977 (Steed et al. 1979) to 471 907 and 78 406 hectares respectively in 1982 (Sly 1984). The former is used more widely as it acts as a direct stomach poison whereas metaldehyde is less toxic and results in paralysis leading to death by dessication. Ideally, control measures should protect cereals from drilling until the start of tillering, as grazing after this time is usually unimportant. Poison pellets are not persistent enough however and usually the main aim of control is to protect the seeds and very young plants from attack. The assessment of whether control is economic, using test-baits, can be misleading as the number caught is strongly dependent on weather conditions. Damage is usually more severe in wet autumns and mild winters especially on heavy clay soils. Slugs cause several types of damage; (i) hollowing out of the seed, (ii) severing the young shoot below ground, and (iii) shredding of young leaves (Gair et al. 1978). Several agricultural practices favour the build-up of slug populations. Oilseed rape provides dense cover during the summer and leaves much debris after harvest providing ideal conditions for slugs and increasing the risk to the following cereal crop. Direct-drilling can also increase the risk from slug damage as plant debris is left on the soil surface. Straw incorporation leads to similar problems; where straw is burnt damage is usually slight but the risk of damage is increased when straw residues remain (Glen et al. 1983).

Wheat bulb fly

Wheat bulb fly, D. coarctata, is especially important on winter wheat. The risk of damage is increased by sowing wheat after fallow, potatoes, sugar beet and other crops with bare soil during the late summer when eggs are laid (Gair 1981). Eggs hatch in mid-January onwards and the larvae bore into shoots, just below ground level, killing the central leaves resulting in the deadheart symptom. In spring the larvae move to new shoots and cause further damage. During May the larvae leave the plants and return to the soil to pupate. Adult flies emerge from these puparia in June (Gair et al. 1978).

Several measures can be used to control wheat bulb fly. Sowing before mid-October in a firm seedbed with adequate fertiliser results in plants able to tolerate some tiller loss but does not lead to a reduction in the fly population (Gair 1981). A number of chemical control measures are available but their effectiveness and costs are variable. Seed treatments of gamma-HCH, carbophenothion or chlorfenvinphos are reasonably effective and economic, although there may be problems with phytoxicity and toxicity to birds. Seed treatments of gamma-HCH also control wireworms. Greater control of wheat bulb fly is given with a treatment of fonofos granules at or near the time of sowing although the costs are higher than a seed treatment, £37/ha and £4/ha respectively. Sprays can be applied at or near the start of egg hatch but timing is important. Redrilling might be necessary in badly attacked crops but an interval of 2-3 weeks should be allowed between ploughing and resowing to reduce the risk of larvae invading the newly sown crop.

Other pests

Several other pests can also be important. Wireworms have already been mentioned with reference to seed treatments. It is likely that too large an area (nearly one million hectares, Sly 1984) is sown with treated seed for the pest levels present (Gair et al. 1978).

Frit fly, Oscinella frit, has several generations each year. It is a pest of spring oats and, in the autumn, of winter cereals especially early sown crops. Crops should be assessed at full emergence and an appropriate insecticide, such as triazophos or chlorpyriphos, applied if larvae are present. Direct-drilling lessens the risk of frit fly damage but crops sown following weedy stubbles can be heavily infested (Gair 1981).

The grass and cereal fly, Opomyza florum, is another species which has benefited from earlier sowing (Short 1981). The yield advantages of earlier sowing, however, more than compensate for the greater losses caused. A range of chemicals have been screened but none have proved entirely satisfactory (Short 1981), and since 1981 damage by this species has not been as widespread as expected, although the reasons for this are not fully understood.

FUTURE PROSPECTS

It is difficult to predict the likely changes in pest control in cereals when the rapid changes that have occurred in recent years are considered. At present the prices of cereals, set by the Common Agricultural Policy in the EEC, are artificially higher than world prices which has encouraged cereal growing, leading to the present surplus. This situation is unlikely to continue. Prices are likely to decline and/or some sort of quota system introduced. Lower prices might result in more cereals being grown as farmers plough more of their marginal land in an attempt to maintain income. Alternatively, variable costs might be analysed more critically leading to a reduction in pesticide usage, if yields can be maintained. This might result in a reduction in seed dressings used against wireworms and the use of aphicides in the summer only when aphid densities warrant it rather than the prophylactic sprays currently applied in tank mixes with fungicides.

More research effort would have to be focused on monitoring, forecasting and the establishment of damage thresholds before farmers would adopt these measures.

For monitoring methods a balance has to be made between accuracy and simplicity. Dewar (1983) recorded presence or absence of cereal aphids on one hundred tillers per field and the resulting percentage infestation converted to density (Rabbinge et al. 1980). Such a method is quick and simple to use and gives a sufficiently accurate density estimate for farmers. Migrant winged aphids are also monitored by suction traps which give good estimates of initial infestation rates (Taylor 1977). The main difficulty is in monitoring and forecasting the subsequent build-up of populations of wingless aphids on crops, which is being studied currently (Dewar & Carter 1984).

Monitoring gives information concerning current levels while the farmer is also interested in future events, ideally right up to the time of harvesting. This involves a forecasting procedure which might consist of 'rule of thumb' and previous experience or at the other extreme, complex computer models dependent on automatic meteorological readings and regular crop monitoring. The rule should always be to use the simplest forecasting method that works. Few reliable computerised forecasting systems are operational in the UK although EPIPRE, a monitoring and prediction scheme for cereal diseases and aphids has been introduced commercially in England. Other schemes, based on agronomic factors, such as time of sowing, variety grown etc., have been developed by chemical companies but do not include a monitoring aspect, so may therefore result in an overuse of pesticides.

Established damage thresholds for many cereal pests are still lacking although the importance of providing these has been stressed (Gair 1981). Even the threshold for the grain aphid, which is considered to be one of the best-founded (Short 1982), is inflexible as it only relates to aphid density at one crop developmental stage. Ideally a variable threshold, over a range of crop developmental stages, should be formulated, based on the data of Lee et al. (1981).

Legislative changes concerning pesticide registration and usage are imminent but the details are not yet available. Possibly the legislation will involve a merging of the Pesticides Safety Precaution Scheme (PSPS) and the Agricultural Chemicals Approval Scheme (ACAS). Although the present voluntary scheme seems to operate reasonably well it is not unknown for farmers to use pesticides for uses for which they have not been cleared. The enforcement of future legal restrictions on pesticide usage would seem a difficult task. This difficulty is not an argument against pesticide legislation but it indicates some of the problems which may arise.

A call for the more rational use of pesticides, on environmental grounds, was made by the Royal Commission on Environmental Pollution (Anon. 1979) and this has been more recently highlighted by a Select Committee of the House of Lords (Anon. 1984b). In the light of this, conservation organisations will increase pressure on chemical companies to disclose more information regarding the properties of pesticides and on farmers to reveal the amounts of pesticides applied and the reasons for their use. This may result in tighter controls being placed on farmers concerning pesticide usage.

Legislation regarding pesticides is not the only restriction which may soon be placed on farmers. Straw burning, a controversial topic, is a practice which many believe may soon be banned. The resulting increase in straw incorporation would favour slugs and might also benefit frit fly, BYDV and fungal diseases.

On the research side several specific areas require further attention. Control of slugs would be improved by the discovery of safe chemicals for seed treatments (Scott 1981) as the current promising ones are too toxic to birds to be approved for widespread use. Further work needs to be done on the agronomic factors favouring BYDV epidemics resulting from non-migrant aphids, the regional influence on the Infectivity Index, and the forecasting of aphid outbreaks in the summer. The development of phenological models for egg hatch for pests such as D. coarctata would improve the synchronisation of insecticide applications with the susceptible stages. Recent trials have indicated that stem borers could be important pests of spring barley (Scott 1983) and more work should be carried out to determine how widespread a problem they are.

It is certain, however, that chemicals will continue to play the dominant part in cereal pest control. Economic and environmental aspects are likely to result in more rational use of pesticides and the incorporation of non-chemical control measures, such as host-plant resistance and the manipulation of natural enemy control agents, as Integrated Control which will have the added benefit of reducing the risk of pests developing resistance.

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DEVELOPMENT OF THE PROTECTION OF CEREAL AGAINST PESTS AND DISEASES IN FRANCE

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SUMMARY

In the present economic climate, characterised by falling cereal prices, only those farmers who achieve the highest performance will improve their returns. They must:-

a. Strive for higher yields in order to finance their heavier and heavier expenses.

b. Reduce their production costs whenever possible.

c. Make better use of factors controlling production, particularly fungicides and insecticides in order to make the best use of the sums invested.

Methods of control already available give satisfactory control of the diseases which are most damaging to yields (programme to help decision making Fongitcf) and also of the most damaging pests.

In order to maintain the competitiveness of cereal growers the efforts of research should be directed to the following points:- the introduction of weather factors in the evaluation of the risk of disease development - improvement of our knowledge of epidemiology - stressing methods for the control of sharp eyespot (Rhizoctonia) and take all (Gaeumannomyces graminis) - observations on the development and health of root systems in order to improve their function (maintenance of soil fertility).

1. CEREAL PRODUCTION SYSTEMS IN FRANCE

A. Development of production (Maquet - not published)

The growing of cereals has undergone important changes in France over the last few years under the effect of the economic situation (EEC Agricultural Policy) and technical limitations (crop potential, environmental adjustment).

Thus far winter wheat yields have increased at a rate of 0.12 tonnes per hectare per year to a mean of 5.2 tonnes per hectare in 1983. The area under cultivation has undergone increase; 4.8 million hectares in 1984 compared to 3.7 in 1971. However, the conditions of climate and soil are very diverse in France and differences between regions are important; for example in 1983 in Eure and Loir (Beauce) the yield attained was 6.3 tonnes per hectare (over 235,000 hectares) while in the same year in Haute Garonne (South-West) the mean yield was 4.5 tonnes per hectare (over 81,000 hectares). It is apparent that in a number of areas the potential technical progress possible remains considerable with a better spread of existing knowledge.

The increase in the area under winter barley has been considerable from 0.4 million hectares in 1971 to 1.4 million hectares in 1984. In contrast the spring barley area has reduced from 2.4 million hectares in 1971 to 0.75 million hectares in 1984. The change in yield explains this phenomenon; on winter barley yield increases mirror those in winter wheat (+ 0.12 t/ha per year reaching 4.9 t/ha in 1983) while in spring barley the yields remain low (3.4 t/ha in 1983).

B. New economic ideas

1984 marked a major change in the Agricultural Policy of the EEC. Since for the first time the price of cereals was fixed at a lower level to that in previous years; this price will move down little by little to meet world standards. It is true that for a number of years farmers' returns have fallen relative to the price of cereals. However, up to the present this drop in price in Francs constant (taking into account inflation) has been more or less balanced by the increase in productivity.

Hence forward those decisions taken in the framework of the new common agricultural policy will have the effect of increasing pressure on the price so that expenses borne by farmers will continue to grow. Thus at the end of 1984 farmers will receive 8 - 10 Francs less per 100 kilos of winter wheat than in 1983 (Francs current price fixed without taking account of inflation).

C. Effect upon farm production

Thus we enter a period where only growers with the greatest performance will succeed in improving their returns. Efforts will have to be made in the following two areas:-

1. Adapting cultural systems to the potential of the soil and of the climate. Thus regional variations will probably increase and will lead to a change in the distribution of crops - an increase in the area of wheat in the Northern half of France and a reduction in the South. There will be a competition for land between winter barley and winter wheat. Spring barley will reduce in area except in regions where major progress is possible (North and East of France) especially for the provision of malting barley.

2. Achieve the highest net margins possible by rigorous management of crop and economics. Farmers will need to act in three directions: (a) Striving for high yields to cover important financial burdens, (b) Reduce the costs of production whenever possible, (c) make better use of the factors controlling production (fertiliser, pesticide etc) in order to make maximum use of the money invested.

Improvement in the profitability of cereals cannot be achieved via a systematic reduction in the use of production factors within the framework of an agricultural system which may expand or contract. Under these conditions the yield of cereals would rapidly drop and would no longer allow costs to be covered.

On the contrary increases in profitability will come from a reasoned increase in the intensification of cropping with regard to production which will necessitate solid technical and economic knowledge by farmers; thus the farmers will be able to rapidly integrate the results of these new systems into their crop management, putting at the disposal of growers detailed and reliable information which would permit them to make decisions leading to high performance throughout the growth of the crops.

In this context we will examine the situation concerning protection against pests and diseases.

II. DISEASES

A. The Situation

The control of cereal diseases by means of fungicides applied during vegetative growth dates from 1972. There has been a considerable increase in the use of such control methods when one considers that in 1983, 65% of cereals (5 million hectares) received at least one treatment.

Winter Wheat

Our trials which have taken place over the last 5 years have shown that such treatments have prevented crop losses varying on average from 0.63 t/ha in 1979 to 1.3 t/ha in 1983. An essential characteristic of these losses is their great variability. Eyespot (Pseudocercosporella herpotrichoides) for example ten years ago was recorded as one of the most important diseases. On the one hand it has been less apparent over the last few years and on the other hand it has been less serious. However, eyespot has created more discussion recently because of the development, since 1983, of strains of eyespot resistant to benzimidazoles (Leroux 1983).

In certain areas of the North of France this appears to have happened quickly. Where this is a risk farmers should use products based on prochloraz.

Farmers are also justifiably anxious about the increase in sharp eyespot (Rhizoctonia cerealis) over the last four years.

One now observes not only the mild symptoms on the sheath but also more and more frequently necrosis of the stem which affects the yield. No reliable method of control can be proposed at present. Of the varieties available Fidel is particularly susceptible to this disease.

We have no way of combating 'take all' which is an important limiting factor in second and third successive wheats.

Fusarium foot rot (Fusarium roseum) is in general superficial and rarely affects yields. Yelllow rust (Puccinia striiformis) only caused serious losses in 1979 and 1977.

Brown rust (Puccinia recondita) is regularly a problem in the South of France, in the North it was severe for the first time in 1983. Over the last few years Septoria spp has been the commonest leaf disease. Fungicide treatments have minimum effect in the control of these diseases. Mildew (Erysiphe graminis) is, in general rare in France, it is more common on wheat where it attacks the upper leaf (flag leaf) and the ear. Ear diseases (Fusarium and Septoria) are a problem from time to time depending upon weather at the time of ear emergence. They can be very severe locally. The data available, at farmer level, on the control of cereal diseases is presented in a programme to aid decisions which can be found:-

- in the form of a leaflet (Fongimetod)
- computerised-television (Fungitcf) (Lescar 1983)

The factors taken into account are of two orders.

On the one hand are the agronomic factors which apply to the condition of the crop in the field. These factors are generally for a given region, and take into account, the previous crop, the cultivations, the date of drilling, the variety and crop density.

On the other hand, it is also known that the state of the crop health can constitute increased risk which will lead to the necessity for treatment. Thresholds are proposed for these. These programmes to aid decision making have been tailored essentially for the North of France.

In the South the evaluation of risk depends less on crop condition and more on weather. At present little is known about which weather factors to take in account in order to aid the farmer in his decision making.

Barley

In winter barley losses are generally greater than in winter wheat, particularly if the affects upon quality are taken into account.

Up to 1981 Rhynchosporium and Erysiphe (mildew) were the most important diseases. Since 1981 net blotch (Pyrenophora teres) must also be included as an important disease. Products based upon prochloraz or propiconazole give satisfactory protection against this group of diseases.

Treatments should be made from the beginning of stem extension to boot, depending upon infection levels. A third period for treatment sometimes occurs at ear emergence if wet weather that is favourable to disease development persists.

Spring barley will only continue to be grown on an intensive system and in particular to supply malting barley. In these cases the fungicide usage and protection will be similar to winter barley.

System for the observation of cereals

Farmers are helped in making decisions by an important system of crop surveillance which has been in operation since 1976. This is operated by the Service de la Protection des Vegetaux of the Ministere de L'Agriculture (de Larocque 1982).

In 1983 1490 observers (56% farmers) monitored 3174 plots of wheat and barley (one plot represented 1934 hectares) (Muckenstrum 1983).

This system is being computerised and the results are being put on videotex (Prestel) in order to facilitate and accelerate the data processing with a view to the distribution of the Avertissement Agricoles.

B. Discussion

Technical factors combining cereal production still exist or are particularly important in the current economic context. So, studies have to be undertaken or developed in the following areas:

The thresholds currently proposed in most cases allow the decision to be made whether a treatment is necessary when the symptoms are visible on at least one of the three top leaves.

The concept of thresholds is not precise enough or dynamic enough to remedy weaknesses in advice; it is important to take into account the weather factors to forecast the risk of disease development (eyespot, rusts, septoria, fusarium on the ear). The objective would be to define the level of risk for the most important diseases by consideration of past climatic conditions (autumn, winter, early spring). This risk could then be modified in the course of the crop development (1 to 2 nodes, boot, ear emergence) depending upon the weather conditions present and the short term forecasts.

To produce an analytical approach one must start with a precise knowledge of the biology of the parasites. However, no reliable model is yet available. Statistical approaches appear to be more realistic even if these cannot be explained from a biological view point.

Thus at ear emergence one advises none, one or two treatments according to whether less than 50 mm, between 50-100 mm or more than 100 mm of rain has fallen in the preceding month. This model is only valid in the North West of France, it has only so far been tested for two years.

This approach merits much more exploration. A better knowledge of the epidemiology of diseases would allow:-

- better timing of control measures with regard to the development of the disease.

- a choice of product dependant on its properties, preventative, curative or eradicant (Lescar 1984). Techniques of artificial inoculation can lead to a better knowledge of the activity of products.

The scientist searches to define the best methods of control, however the farmer himself cannot always make the applications under ideal conditions; when other operations have to be performed or when the weather interferes, it would be preferable to know the exact risk being taken when straying from the optimum. Should he apply the treatment quickly, if time permits, even it he is a little early, or should he wait with the attendant risk of having to delay treatments because of the rain and thereby losing some of its effectiveness.

The only resistance problem recorded in cereals in France has been that with eyespot and the benzimidazoles. It is certain that further intensification of cereal production will mean a greater reliance on fungicides. Thus the risk of fungicide resistance developing would be increased. (Leroux 1983) It is advisable for farmers to diversify their choice of cereal varieties and to alternate the fungicides used. It is thought that this strategy will have the effect of at least delaying the appearance of other resistant strains but no one can say for how long.

Progress thus depends equally upon the success of the search for new molecules, diversification of the mode of action of fungicides against diseases, particuarly eyespot and the search for fungicides with activity against Rhizoctonia and take all.

Reductions of treatment costs by the reduction in volume of spray seems limited in the case of insecticides and fungicides. Contrary to what happens with regard to herbicides one takes a risk of lower performance when one reduces volumes to below 150 - 200 l/ha even with a well regulated sprayer. Reduction of amounts of active ingredients could also be unreliable.

Barley Yellow Mosaic Virus has extended to winter barley in the East and North of France since 1980. The damage can be serious and in spring

1984 more than 1,000 hectares were recorded as being affected in the Champagne area. Spring barley is not affected by this disease. In France wheat is equally affected by Common Mosaic (SBWMV) which has been conspicuous since 1975 and also by Yellow Mosaic which is now causing damage in the South West of the Paris basin (losing 2 to 3 tonnes per hectare in severe cases) (WYMV).

The spread of these viruses which are transmitted in the soil by Polymyxa graminis can be explained in part by heavy autumn rains, cold springs and the repeated use of susceptible varieties in the same fields over the past few years. The only reliable method of control lies in the development of resistant varieties. Few of the varieties of winter barley are resistant and the susceptible varieties of wheat, which were few in 1981, increase each year. Fidel and Lutin can be recommended.

The aim of plant breeders must be to develop or select varieties which do not allow the virus to multiply, in order to reduce inoculum pressure.

We are now carrying out trials in areas contaminated with the virus. It is feared that in certain areas winter barley growing might cease if varieties which are tolerant and sufficiently productive are not available on the market.

III. PESTS

A. The Situation

The list of pests able to cause damage to cereals is important but from the practical point of view these attacks are more often periodic and local losses due to pests are, in general, less severe than those from diseases. However, one can note several examples of extensive damage recorded over a period of approximately 15 years.

The tortrix moth (Cnephasis pumicana) on winter barley in L'Aube in 1974 (losses of 2.5 t/ha).

The cereal leaf miner (Agromzya nigrella) on spring barley in Le Loiret in 1975 (losses of 0.8 t/ha). Wheat blossom midges (Contarinia tritici and Sitodiplosis mosellana) on wheat in the Pas-de-Calais in 1970 (losses of 0.7 t/ha).

Sitobion avenae on wheat in Seine and Marne in 1975 (losses of 1.8 t/ha).

The bird cherry aphid (Rhopalosiphum padi) the vector of Barley Yellow Dwarf Virus in winter barley in Vendee in 1982, yields did not exceed 0.05 - 0.3 t/ha in 90% of the fields. Decisions about control are based on population levels, development, weather conditions and the growth stage of the cereal.

For several years the relative importance of the different pests has been recorded, those that are the most frequent are aphids in the autumn, ear or grain aphids and slugs.

Insecticide treatments for the control of these pests were carried out on large areas 1.5 million hectares in spring 1983 and 400,000 hectares were treated in autumn 1983 for the control of BYDV vectors in winter barley.

B. Discussion

As in the case of disease control, the farmers have to have access to and to implement all the technical information available. The system of cereal monitoring plays an important role in this. In other respects the protection of cereals against pests causes a number of questions which have to be resolved in order to improve the profitability of cereals and promote the sensible use of insecticides.

Autumn Aphids

A decision matrix for the control of BYDV on barley is proposed by Bayon in Poitou-Charentes (Mouchart 1982). The factors taken into account are the presence of volunteer cereals, number of migrating aphids caught by the suction trap method, Actaphid, the increase in number of plants infested with aphids, their duration of infestation and the temperature. Protection against BYDV has been improved in particular in other regions by a better definition of the data or dates of spraying commencing from these factors.

Ear Aphid

A model to forecast outbreaks of aphids using weather data is used in the West Atlantic Zone (Dedryver 1983), it could be improved and adapted to apply to the Paris basin.

Wheat and maize harbour the same species of aphid in turn and one can therefore imagine that a better knowledge of the aphids' development or alternative hosts would permit the establishment of models to predict outbreaks and to identify seasons and areas where there are potential risks. Thus it should be possible to know whether to make a treatment, delay it or avoid it altogether (Fougeroux 1984). Taking into account the wide variability of attack in fields within the same region such forecasting can only be a guide as to observation fields which are of course indispensible.

Other Insects and Outbreaks

Chambon (1982) put forward evidence that there is a lower number of species in the cereal zone of the Paris basin which regularly receives insecticide sprays in comparison with an area less often treated. Within the total number of species trapped harmful species represent a larger percentage in the treated zone. The author estimates that this impoverishment of beneficial insects in favour of harmful could aggravate pest problems, not only in cereal culture but also in other crops.

In maize outbreaks of Rhopalosiphum padi have been observed following treatments with pyrethroids to control European corn borer (Ostrinia nubilalis). The special morphology of this particular cereal crop allows the aphids to hide from treatments in the female inflorescences which would explain this phenomenon.

However, no one has observed abnormal disturbances of the fauna of wheat or barley in spite of the continued use of insecticides, nor has any resistance to the products used been observed.

Other pests

The control of wheat bulb fly (Delia coarctata) needs to be improved. The research into new seed dressing products to give control over the early post emergence period has not yet been completed.

A better knowledge of the biology of slugs would give precise times and methods of cultural control which would have the effect of reducing population levels, especially of underground species which are the most damaging. The removal of straw (by incorporation, burning or carting) and the cultivation of soil in combination with chemical treatments is the best method of control.

Nematode damage is sporadic. Amongst the species involved is Heterodera avenae this is the most feared. Trials, Ambolet 1983, showed that this species was the most frequent in the first years of continuous cereals but never reached levels sufficiently high to cause damage. The populations then decline. Two hypotheses are proposed:-

1. Continuous cropping of wheat produces plants of low nutritional value not so suitable as food for H. avenae.

2. Parasitism reduces the population of this nematode.

IV. RECENT TRENDS

Within the framework of new economic constraints to be imposed upon farmers in the years to come there appears to be no contradiction between technical objectives and the necessity for a more rational use of pesticides. In particular it is only by better use of production factors, namely pesticides, that the production factors can be improved.

There are two areas of research which further assist the cereal grower in his approach and offer the possibility of increased potential from his crops.

1. Varieties

An important trump card in the hand of the producers is the ability to use varieties which allow them to limit the risk of disease. A new opening in this area is the develoment of hybrids obtained by chemical means. This technique offers a means of more rapid research than traditional methods of selection.

It enables the breeders to supply to the market varieties resistant to certain problems (Rhizoctonia, Mosaics, Nematodes etc) or to combat the evolution of new races of parasites.

In this area, as in the past, there will not be competition between genetic control and chemical control but, on the contrary, reinforcement of one approach by the other. It is at present true that fungicide treatments for example permit access to higher yields measured against crops which already possess a good tolerance to the diseases.

2. Soil Sickness

In trials in progress since 1977 (Ambolet 1983) the yields of continuous wheat are shown to plateau after several years and produce yields 10-25 % lower than single wheats. Continuous wheat shows a lower vigour following germination and emergence and tillering is reduced compared to a wheat source at the same date following sugar beet. Thus the crop shows lower ear count and shallower rooting.

Any practice of continual cropping does not permit attention to these factors limiting production.

The effect of break crops is shown equally well by disinfection of soil with products such as methyl bromide. However, the normal causes of low yields (eyespot, nematodes) in such a situation are not adequate to explain these phenomena.

One can suppose (Bouhot 1982) that an interaction between such diverse factors as physical, biological and nutritional is the origin of reductions in productivity. The limitation to the yield of wheat can also show itself in rotations as well. The causes are little known and are collected together under the general term 'soil sickness'. Tests have been instigated with the goal of diagnosing the causes of such sickness. Preliminary results suggest that within the trials the principal limiting factors are biological in origin (fungi, etc).

This work, which has only just started, appears to be very promising in effect, the potential of the crop is in a large part fixed by the placement of the crop, no vegetative treatment giving improvements if the original potential is not present.

It therefore seems necessary despite the difficulties of methodology to undertake observations on the development and results of the root system in order to improve its function (by adaptation of cultivation techniques, soil pesticides etc.)

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CEREALS, PEST AND DISEASE CONTROL IN RELATION TO CROP HUSBANDRY - A FARMER'S VIEW

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INTRODUCTION

My own 450 hectare farm has grown to this size over the fifteen years that I have been there and, except for a six year foray into eighteen month beef, has remained in cereals and rape. The business has expanded as a direct result of the attention to detail that is so necessary to maximise the return on capital on what is a grade III soil. Managing a farm business is all about priorities and compromises. With a small, highly capable and motivated team, every decision can be taken in the minimum of time and with total involvement. Effective management of a farm's resources can be best achieved by all members of one's team knowing exactly the way ahead and much of the detail on my farm is carried on by the individual members of staffs' own motivation.

Our overall objectives on the farm are:-

1) to maximize the return on Tenant's Capital;
2) to practice all aspects of good husbandry with efficient use of resources;
3) to maintain a standard, out on the farm and in the buildings, of which all the staff can be proud.

Within the constrictions of future E.E.C. policies and environmental pressures it is going to be increasingly difficult to maintain our standards but that is what we must do. And so. what is our approach to Cereal Pest and Disease Control? Can we look at the three aspects:-

Crop Potential

We know from individual field weights that we can grow 8.6 tonnes/ha of reasonably sized blocks of wheat and in 1984 exceeded 10 tonne/ha., but the moisture retention limitations of my clay with flints over chalk soil will limit our budgeting to 7.4 tonne/ha on individual fields and 6.4 tonne/ha overall. The economic factors I will return to in a minute ..... You must attempt to relate to my own circumstances when I say that I am in an A.O.B. and still have the original 42 fields I had in 1968, therefore an average field size of 10 ha. 70% of my field boundaries are bordered by woodland: a variation in altitude from 250 ft - 700 ft and a soil variation of pure chalk to a medium clay with flints overlying areas of intractable red clay subsoil.

Application

Our method is still via the hydraulic nozzle, well maintained and well monitored to give speedy and efficient operation and flexibility with chemical type. We have looked hard at the vast range of options open to us and decided that we could no longer tolerate heavy spraying equipment because of crop loss, and so now operate a L.G.P. vehicle with low all up weight and narrow wheel capability - this last point is vitally important with early drilled crops, so forward in growth stages in March when tiller damage with wide wheels can be unacceptable. I might add that we, like many farmers, have not been impressed and much frustrated by the infighting within your industry about the merits and/or safety aspects of C.D.A., Electrostatics et al. Yardsticks for sprayer output are always being quoted and are very subjective, so much depending on one's own circumstances but one is very aware one must have the capability to cover 30% - 40% of any one crop type per day. Our own system is now perfected by my staff to the extent that cab displays are allowing such precision that no over-ordering or over-applying occurs. We do not dabble in reduced rates of active ingredients but we do feel happy with reduced water rates with our accurate metering systems.

Taking you through the crop year, only the winter wheat following rape requires molluscicides and only after test baiting, but this will be an increasing problem with straw incorporation. The farm rotation on the main blocks runs rape, wheat, wheat, winter barley, winter oats, and whilst good burning has been possible, a grass bridge has been avoided so minimizing frit fly attack.

General field hygiene hopefully avoids B.Y.D.V. vector carry over but since most drilling is completed by 5th October, we are being forced to a prophylactic spray of pyrethroids. One is aware of possible leatherjacket attacks even in continuous white straw crops.

The winter barley will have been seed dressed with 'Baytan' (triadimenol with fuberidazole) giving cover for the crop through to the spring every year, when more than 10% mildew infection would necessitate a further mildewicide. Winter wheat, from recent evidence, will receive triadimenol with fuberidazole dressing if in second or third wheat, when September drilled and in high risk take all, Fusarium and eyespot situations. In the spring, evaluation of eyespot levels on all winter barley or wheat will lead to spraying of either prochloraz or carbendazim at levels in excess of 15% - 20% tillers infected at G.S.6. Alternate use of these products is now being deliberately carried out on the farm. Yield responses are being noted irrespective of level of infection. Also at G.S.6. high levels of mildew will also be covered by propiconazole. At this time any level of Septoria tritici is being reduced by carbendazim. Disease monitoring from G.S.8. onwards is for spraying "as seen" in the absence of as yet any more precise method of disease control. Awareness of previous weather, topography and varietal resistances are always foremost in my mind. Standard rates of propiconazole, captafol, triademefon are used for Septorias, mildew, yellow rust, brown rust or net blotch. If the crop is clean at G.S.8. all crops will be sprayed at G.S.9. - 10.1 with either propiconazole or triademefon plus captafol. These two mixtures are deliberately varied. Complex mixtures including carbendazim are avoided because of the problem associated with sharp eyespot.

Aphid control at pre-flowering in wheats is carried out using mostly dimethoate at standard A.D.A.S. aphid thresholds.

The problem areas still seem to be early disease recognition and/or prediction. Whilst all of us can recognize diseases in their normal and developed form, all too often that is too late. Prediction must be a course for the future and computer models coupled with accurate local weather data.

At this point I would like to make a plea to this gathering that more thought be given as to how an individual farmer or group could have access to locally collated weather data and this, coupled with the more precise forecasting that may be not so far away, could be of considerable value in a decision making process that for the individual farmer, however expert he may be, is still a very grey area. Could it not be that a farmer group within a small, similar geographical area could subscribe to the automatic weather data system and including insect traps. This, tied in to an individual's computer must be the way ahead. A particular problem was highlighted to me last autumn when agonizing over whether or not to spray for B.Y.D.V. protection. Totally opposing infectivity indices were issued to me from two stations, twenty miles each side of me.

Cost Effectiveness

Now, on to the more thorny subject of the cost effectiveness of pest or disease control. Here the farmer is in a dilemma. Does he rely upon the knowledge and integrity of his adviser, or should he be involved in every decision making process in the Agrochemical scene? I would hasten to suggest that despite the ever greater role the adviser will and must play, with the increasing sophistication of his subject, the subsequent effect on the profitability is greater now that it has ever been. For this reason, may I make another plea to you as Agrochemial manufacturers and suppliers? What about your priorities now? Direct your energies and monies away from futile bits of paper littering farmers' letterboxes and wastebins - we are not that gullible. I estimate that if I did what you suggest in your literature I would see an economic benefit from all your products even if used imprecisely. With the new climate emanating from Brussels, we farmers need - and will only be interested in - well documented and proven data from unbiased, non-commercial centres such as the Cotswold Cereal Centre and A.D.A.S. Centres. I sadly deplore the cutbacks in A.D.A.S. because the Regional Centres are providing valuable information and I hope your industry will see the sense in supporting more independent centres producing well proven data.

The Economic Factors - the conditions of the autumn - Christmas '83 period that probably gave us the freak yields of '84, have only delayed the real problem of declining margins and what does the cereal farmer do to minimize this pressure? The cereal specialist is locked into a slimline fixed cost structure, the only possible manoevre is delayed re-investment but one thing is at present certain, there is more pressure than ever to increase yield with the prudent use of the variable inputs. This, of course, will only exacerbate the problems for Brussels but under the present regime we have no alternative.

Alternative crops will have their place, some may stem the rise in fixed costs, others could reduce overall farm net margins further.

The graph highlights what was the budgeted gross margin and what in fact happened in 1984. Had the yield line not taken off, there might well have been a different atmosphere in the conference hall this week!

One of the problems writing this paper as a farmer, has been that one cannot easily isolate one aspect of crop husbandry in economic terms, since at this present time, other cost factors are of some concern - although not strictly within the brief of this paper. Let us not forget that whatever method of straw disposal is used, other than burning, it is likely to be very expensive. No burning will increase slug activity probably exaggerate levels of eyespot, take all and fusarium and if one assumes that the return to the plough is possible within the structure of most businesses, chopping and incorporation, or enzyme application if it is a proven technique, together with increased agrochemical usage will reduce the margin of winter wheat on my farm, with my cost structure and yield levels, by approximately 20%. Let us not fool ourselves - incorporation is not easy; chopping is nowhere near perfected; burning is enjoyed less by the conscientious farmer than by anybody else - and so this is another carrot to be dangled in front of the agrochemical industry either in the context of degradation or alternative use of the straw.

And so, Ladies and Gentlemen, that is a farmer's view of what in practice is the most complex area of the arable farmer's day - but the graph, Fig. 1, will perhaps easily summarize what has been happening and might well be in store for us. Do not overlook that this graph is only looking at winter wheat. Barley already on my farm has to exceed 5.4 tonnes/ha to break even on my cost structure. A 10% fall in price will equate to a 42% fall in net margin with 6% inflation. The break even point of wheat is 1 tonne/ha higher now than in 1980.

FIG. 1