HGCA

PROJECT REPORT 315

MANAGEMENT OF RHYNCHOSPORIUM IN DIFFERENT BARLEY VARIETIES AND CROPPING SYSTEMS

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by

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Abstract

The barley disease commonly known as Rhynchosporium, caused by *Rhynchosporium secalis*, has become difficult to control with fungicides. In this project, Rhynchosporium was observed throughout the season in both winter and spring barley varieties and the importance of fungicide timing on disease control and yield recorded. These trials also gave an insight into why variety resistance ratings for winter barley tend not to perform as well as expected in high disease pressure regions. Rhynchosporium levels reached their peak in winter barley from boot growth stage (GS49-69) on the lower leaves. A second peak of disease was seen on the upper leaves at GS70-80. Variety resistance ratings are predominantly based on assessments carried out later in the season when disease levels can be lower than those seen at the boot growth stage.

The efficacy of individual barley fungicides was investigated before looking in more detail at fungicide mixtures, which achieved effective control of Rhynchosporium. The impact of the mixtures on protectant and eradicant control of Rhynchosporium was observed along with their effectiveness against other important diseases and yield. An experimental fungicide (HGCA3*) achieved the best control and yield benefits. Strobilurin fungicides were a useful component to control Rhynchosporium but their impact on green leaf area was less apparent compared to when they were first used on barley. Chlorothalonil had a positive impact on green leaf area, but little impact on yield, whilst cyprodinil had a greater effect on yield when applied early on winter barley than in spring barley. Morpholine fungicides had a negative effect on yield in spring barley, but this fungicide group has a useful short-term effect against Rhynchosporium.

Rhynchosporium isolates taken from trials were tested for their sensitivity to the fungicides epoxiconazole, flusilazole, carbendazim, cyprodinil and azoxystrobin. Patterns of sensitivity to epoxiconazole were also monitored over the three years of the study. The testing was carried out to see if the use of specific mixtures or if sequential use of the same fungicide influenced the sensitivity of Rhynchosporium as the season progressed. Rhynchosporium isolates were found to vary in their sensitivity to epoxiconazole from site to site and the populations tested are starting to show a similar pattern of sensitivity to that seen with older DMI fungicides (triazoles) which are no longer important Rhynchosporium fungicides.

It was observed that Rhynchosporium isolated from the resistant variety Pewter appeared to be more sensitive to triazole fungicides than those taken from Riviera. This suggests that Rhynchosporium strains, which are able to develop on resistant varieties, may be easily controlled with triazole fungicides.

*HGCA3 refers to the code used in Winter Barley Appropriate Dose Project 2496

Summary

Symptoms and development of Rhynchosporium in spring & winter barley

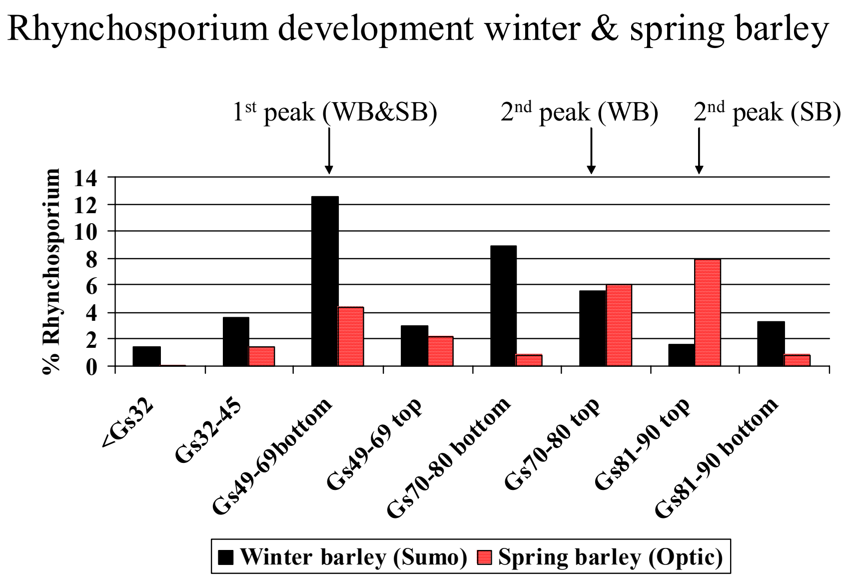
Rhynchosporium secalis is a fungal disease, which attacks both winter and spring barley, along with other hosts, including grasses. The disease, which is commonly known by growers as Rhynchosporium, over-winters in barley trash and it spreads onto crops predominantly through rain splash. As the barley crop develops new leaves, the fungus will splash up onto the upper leaves during wet or showery weather.

It is common for winter barley crops and winter sown spring barley to show Rhynchosporium symptoms in the autumn and early spring. This means the disease is usually present in the crop when growers treat the crop with a fungicide in the spring. The older leaves die-back, particularly during dry spells of weather in the spring, but lesions on these older leaves are a source of the fungus which splashes onto the new growth, These spores are the initial cause of Rhynchosporium lesions which affect the green leaf area, which in turn, results in a loss in grain yield and quality.

Typical symptoms comprise small pale green to brown water soaked marks on the leaf. Sometimes they occur at the leaf base, but they can occur anywhere on the leaf. This early symptom develops into a typical pale lesion with a dark brown border. The lesions can coalesce leading to death of large areas of the leaf. Lesions which develop at the base of the leaf can sometimes cause the whole leaf to die.

Spring sown spring barley crops can start to show symptoms at late tillering stages. This gives growers the option to apply a fungicide before symptoms occur. Since fungicides are more effective at protecting crops against the disease than eradication, managing Rhynchosporium in spring-sown barley can be relatively straightforward. Waiting until symptoms occur before treating the spring barley crop can lead to the difficulties typically experienced with winter crops.

Figure 1 shows the development of Rhynchosporium in winter and spring barley during 1999-2001 based on growth stages. In the winter and spring crop, Rhynchosporium levels reach their first peak of disease on the lower leaves at GS49-69 (boot stage to flowering). The winter crop reaches a second peak of disease on the upper leaves at GS70-80 (watery to milky ripe). In spring barley, the second peak of disease on the upper leaves occurred later at GS81-90 (milky ripe to soft dough).



(SED Winter barley +/-0.209%, spring barley +/-0.135%).

Reviewing growth stage survey data collected during the season from commercial crops, the dates and growth stages where these Rhynchosporium disease peaks occurred are given in Table 1.

Table 1 Growth stages and dates when Rhynchosporium reaches a peak in spring and winter barley

Peaks of Rhynchosporium	Leaves affected	Growth stage	2000	2001	2002
1st peak Winter barley	Bottom	GS49-69	10May-7 June	25May-22June	20May-3June
2nd peak Winter barley	Top	GS70-80	14June-5July	22June-6July	3June-1July
1st peak Spring barley	Bottom	GS49-69	21June-5July	29June-6July	17June-1July
2nd peak Spring barley	Top	GS81-90	19July-1Aug	27July-17Aug	15July-1Aug

Growth stage dates in Table 1 are based on ‘Adopt a Crop’ data collected in Scotland. The second peak of disease in winter barley coincides with the first peak of disease for spring barley. It is also possible that the second peak of disease for spring barley can coincide with the sowing of the following seasons winter barley crop.

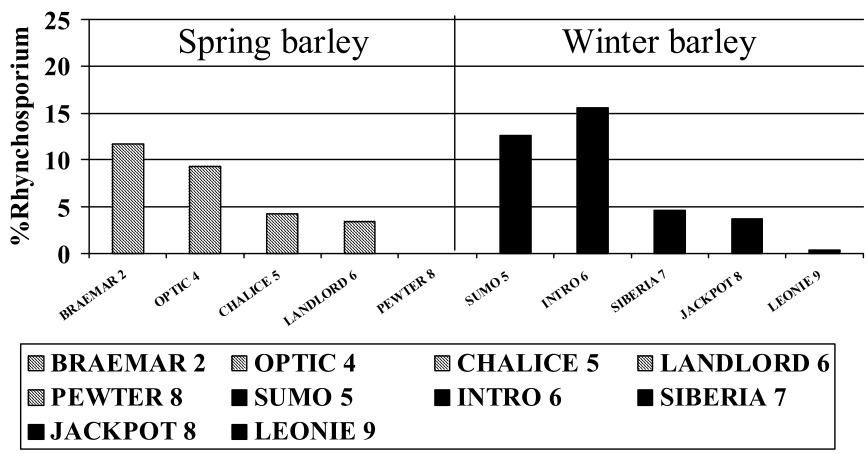
It should be emphasised that growers cannot wait until the peak in disease symptoms before treating the crop. Preventative action is required in advance to ensure no damage is done.

Variety resistance

In the field, differences in the susceptibility of spring barley varieties tend to follow the resistance rating in the Recommended List. In areas where Rhynchosporium is a problem, the winter barley varieties tend to be more susceptible to Rhynchosporium than the allocated resistance rating suggests. Figure 2 compares disease levels in winter and spring barley at high disease pressure sites over a range of resistance ratings. Winter varieties with resistance ratings of 5 and 6 have more disease than spring varieties with ratings of 2 and 4. Winter varieties with resistance ratings of 7 and 8 have similar levels of disease to spring varieties with resistance ratings of 5 and 6.

It is recommended that this mismatch between the winter and spring barley ratings for Rhynchosporium should be addressed in future Recommended Lists.

Figure 2 Comparison of Rhynchosporium levels in winter and spring barley varieties with specific resistance ratings (data based on late assessments)



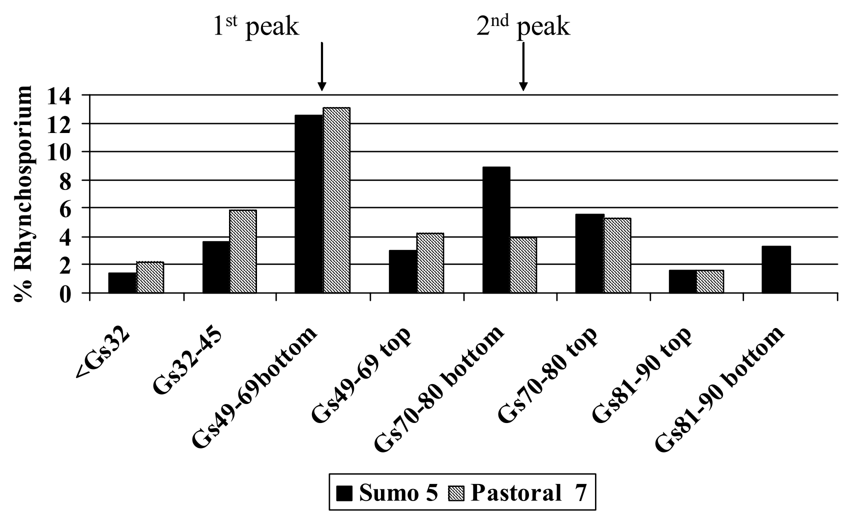
Number next to variety = rhynchosporium resistance rating

(SED Spring barley +/-3.98%, Winter barley +/-2.39%).

The majority of data used from Recommended List (RL) variety trials to determine Rhynchosporium resistance ratings are taken late in the season. If you look back at Figure 1, you can see that this late assessment timing would reflect the second peak of disease in the winter and spring crop. This poses no problem for the spring barley crop, since this is the time where Rhynchosporium levels reach their peak. It may however cause problems in some winter barley varieties since the major peak of disease occurs earlier in the season. In Pastoral, for example, the level of disease seen in the first peak of disease tends to be higher than levels seen later in the season (Figure 3). By the time assessments are done late in the season, it is likely the lower leaves with Rhynchosporium have died-back so are ignored in the plot assessments late in the season. As a result, Pastoral will score low for disease, resulting in a high resistance score

This may not be easy to resolve in variety trial field assessments, but if disease does develop early in a trial, it would be useful to score it to ensure varieties which are affected most early in the season get resistance ratings which reflect this.

Figure 3 Comparison of disease level on Pastoral and Sumo during the season (Average 2001 & 2002)



(SED +/- 2.39%).

Fungicide efficacy

Rhynchosporium is a difficult disease to eradicate with fungicides but it is relatively straightforward to protect crops against the disease. Table 2 shows a ranking of fungicides used in this study. All three mixtures tested in the log dose trials are at the top of the table, whilst it was rare for any individual fungicide to achieve greater than 50% control.

Strobilurin fungicides were at the top of the single product list, but azoxystrobin (Amistar) was less effective. The strobilurins were followed by chlorothalonil (Atlas Cropgard), cyprodinil (Unix) and the DMI (triazole) fungicides HGCA3 and Opus. The morpholine fungicide fenpropimorph (Corbel) achieved 33% control. It is acknowledged that where fenpropimorph (Corbel) is used alone, it is a poor Rhynchosporium fungicide. It does however provide an initial check to the disease, but this effect is short lived. Fenpropimorph (Corbel) is therefore a useful fungicide to use in a mixture where Rhynchosporium is already established in a crop. Spiroxamine (Torch) is a similar fungicide to fenpropimorph (Corbel), but is less effective in this short-term eradicant role. Punch C is a mixture of flusilazole + carbendazim. Rhynchosporium isolates were found to be insensitive to both active ingredients which explains why disease control is now lower compared to a few years ago. Maneb achieved no control in these trials.

Table 2 Comparison of fungicides used to control Rhynchosporium (mean of winter & spring log dose trials)

Fungicide name & dose (l/ha or kg/ha)	**Fungicide type**	**Mixture(M) or Single product (s)**	**Average % Rhynchosporium**	**% Control**	
Unix 0.67+ Twist 1.3	Unix + Strobilurin	M	1.8	86%	**Best**
Landmark 1.0	Triazole + Strobilurin	M	4.5	66%	
Opera 1.5	Triazole + Strobilurin	M	6.1	55%	
Twist 2.0	Strobilurin	S	6.3	53%	
Acanto 1.0	Strobilurin	S	6.4	52%	
Atlas Cropgard 2.0	Chlorothalonil	S	6.4	52%	
Unix 0.67	Unix	S	7.4	44%	
HGCA 3 0.8	Triazole	S	7.8	41%	
Opus 1.0	Triazole	S	7.8	41%	
Amistar 1.0	Strobilurin	S	8.3	38%	
Corbel 1.0	Morpholine	S	8.9	33%	
Punch C 0.8	Triazole + MBC	M	9.0	32%	
Torch 1.5	Spiroxamine	S	10.5	22%	
Maneb	Dithiocarbamate	S	13.4	0%	
Untreated	-	-	13.3	-	**Worst**
SED +/-1.349%					

Fungicide mixtures

The mixture trials were carried out in one season only, but there are useful patterns on what products are contributing. HGCA3 achieved significant benefit over other products as far as Rhynchosporium control is concerned. Strobilurin fungicides also achieved a benefit over other fungicide groups. This is good news, but with recent resistance problems with strobilurin fungicides, it would be a concern if resistance did occur in Rhynchosporium to strobilurin fungicides. The impact of fenpropimorph was not so obvious, but this fungicide can achieve a short-term eradicant activity when used in a mixture. Watch out for negative effects on yield whether it is applied late however.

Yield response to treatment

The best yield benefit was found where HGCA3 was used in a mixture and this is worth up to an additional half a tonne per hectare. When the product is approved, it may be tempting to use this product throughout the programme. Since it is in the same group of fungicides as epoxiconazole (Opus), caution will be required on over using the product in order to keep the benefits of the fungicide in the longer term.

Chlorothalonil also achieved an effective yield benefit when used in a mixture. The chlorothalonil yield benefit may be a seasonal factor however, since it did benefit green leaf area, which in 2002 was converted to yield.

Cyprodinil achieved better yield response in winter barley than in spring barley. It also performed best when applied early. This can be explained by the additional disease control the fungicide provides, in particular eyespot, which will be more of a problem in the winter crop. It has been shown to be less effective against Ramularia and leaf spots than other fungicides, in particular epoxiconazole and chlorothalonil, hence it will give poor activity later in the season.

Fenpropimorph (i.e. Corbel) had a negative effect on the yield in spring barley. This may be more severe in wet seasons. Using a morpholine late in the season in these circumstances can affect green leaf area, which can reduce yield. Since the strength of Corbel is in Rhynchosporium (and mildew) eradication, the best approach would be to ensure both diseases are well controlled early in the season early so reducing the necessity for disease eradication on the upper leaves.

Fungicide resistance

Resistance to DMI (triazole) fungicides occurs on a sliding scale rather than the 'all or nothing' type of resistance seen with powdery mildew and strobilurin (QoI) fungicides. Experience from older DMIs shows that as a Rhynchosporium population is exposed to fungicide usage it gradually splits into sensitive and less sensitive components. From 1998 until 2001, there has been a shift for the DMI fungicides epoxiconazole and the population distribution is showing a similar pattern to the older DMI triadimenol, which is no longer an effective barley fungicide. This change means the fungicide dose required in 2001 to give similar levels of control in 1998 would have to be increased. This project also shows that the sensitivity of the DMI fungicides varies from site to site as well as from year to year. It was also demonstrated in this project (as was seen in previous HGCA research) that a shift occurs where a DMI fungicide is used more than once in a season.

No changes in sensitivity to cyprodinil (Unix) were detected in this study and there were no differences between sites. This makes this fungicide more reliable in the type of control you will expect, but when used alone it is unlikely to achieve fully effective control. There was no shift to the QoI fungicide azoxystrobin (Amistar) during this project. Recent changes in resistance to this group of fungicides to Septoria tritici in wheat do mean that this situation has to be monitored more closely, particularly since this group of fungicides currently contributes a lot to the control of Rhynchosporium.

Testing of the two active ingredients in Punch C (flusilazole and carbendazim) demonstrated that a pattern of sensitivity to flusilazole was similar to older DMIs, whilst Rhynchosporium isolates resistant to carbendazim were common in the sites tested.

An interesting observation was seen with the Rhynchosporium isolated from the spring barley varieties. Pewter shows reasonable varietal resistance to Rhynchosporium, but it does get attacked. The Rhynchosporium present on the variety was more sensitive to DMI fungicides than the Rhynchosporium present on the variety Riviera. If this is a consistent effect, it suggests that some varieties, which are more resistant to Rhynchosporium, may be first attacked by Rhynchosporium, which is more sensitive to fungicides. This would assist growers since the disease would appear at lower levels and may also be easier to control with DMI fungicides. Whilst there are effective fungicides, this finding may be more academic than practical, but if the fungicide choice becomes limited, it could help manage Rhynchosporium disease.

To reduce further shifts towards resistance to DMI fungicides, it is recommended that they are not applied in every treatment and always in mixtures with other fungicides. Although sensitivity to other fungicides used in this study appears more stable, similar guidelines would be a sensible precaution. The fungicide programmes below take account of the findings from this project. HGCA3 has not been included in the guidelines since it currently has no Approval, but lessons learnt from epoxiconazole may also refer to this new DMI fungicide.

Fungicide programmes

General guidelines on timing of treatments and product choice can be made using the results from different sections of this report. When devising these guidelines, the fact that other diseases may also be present or a potential risk has to be taken into account.

Winter barley

Autumn: Rhynchosporium is likely to develop in the autumn, but no action is recommended at this stage.

Early spring: Rhynchosporium, which may have developed over the autumn and winter, may be present on the bottom leaves. When the crop starts to grow in the spring, it is recommended a fungicide mixture is applied to protect the developing leaves. Although these leaves may not be major contributors to yield, the aim of protecting the crop now is to prevent an upsurge in disease at GS31-32.

Corbel is a useful component of the mixture due to its short-term eradicant activity. The preferred mixing partner would be Unix, which will provide Rhynchosporium protection.

GS31-32: This is a key timing to ensure the crop is protected to prevent the first peak of Rhynchosporium developing. Unix is the main fungicide due to its broad-spectrum disease protection properties for all major diseases except rusts. When mixed with a strobilurin fungicide, this will ensure effective protection of Rhynchosporium. If no earlier fungicide was applied, or if fresh Rhynchosporium lesions are developing, then the addition of a morpholine fungicide (Corbel) will help eradicate developing Rhynchosporium. Although triazole fungicides are an option, it is recommended they are avoided to minimise the exposure of the crop to this group of fungicides. Triazole fungicides have greater benefits used later in the programme.

GS45-49: At this stage, the role of the fungicide mixture is to protect the upper leaves from Rhynchosporium at the second peak. At this timing, the triazole fungicide plays an important role along with the strobilurin fungicide to protect the crop from Rhynchosporium along with other major diseases, including rusts, net blotch and leaf spots. Assuming no disease is established on the upper leaves, a morpholine fungicide should be avoided, since using this type of fungicide at this growth stage can sometimes cause premature leaf death and yield loss. Chlorothalonil, however, is an option to assist protecting the upper leaves from Rhynchosporium. Unix should be avoided at this growth stage, since it may have been used twice already in a programme and it is weaker on leaf spot diseases and has compatibility limitations with some plant growth regulators.

By using fungicides no more than twice and in mixtures, it may be possible to minimise the potential risk of resistance to any particular fungicide. The programme is, however, reliant on strobilurin fungicides playing a major role in controlling Rhynchosporium. If there are any changes in resistance of this group of fungicides to Rhynchosporium, the guidelines will need to be reviewed.

Spring barley

Early spring: In spring barley, an early spring treatment for Rhynchosporium is unlikely to be required (at seedling growth stages). Mildew susceptible varieties (e.g. Optic) may require early mildew control with morpholine +/- quinoxyfen or HGCA5, but these fungicides will not protect the crop from Rhynchosporium. Occasionally chlorothalonil may be applied early with herbicides, but in most situations this may not be required.

GS25-30: This is the main time to apply a protectant fungicide to the crop to protect the crop from the first peak of disease. This can be based on Unix + a strobilurin fungicide, but chlorothalonil or a triazole fungicide are other options. The morpholine (e.g. Corbel) would only be required if Rhynchosporium or mildew were already established.

GS37-39: Growers, who are reluctant to protect the crop earlier, may find disease starts to develop at this time. This situation should be avoided, since Rhynchosporium can be difficult to eradicate. If Rhynchosporium has started to develop, a morpholine fungicide will have to be applied. This type of fungicide may affect the green leaf area on the upper leaves under certain conditions. Flag leaf emerging stage (Gs37-39) is too early to achieve effective protection of the upper leaves against leaf spots. This compromise spray timing may suit lower input feed barley systems where the Rhynchosporium disease pressure was low earlier in the season and where quality (in particular screenings) are not important.

GS45-49: This is the optimum timing to protect the crop from the second peak of Rhynchosporium infection and also from leaf spots. A triazole + strobilurin mixture will be a good approach to use, but if the risk of leaf spots is high or the weather conducive to Rhynchosporium, chlorothalonil will be another option to consider in the mixture. For malting barley crops, some triazoles should not be applied if any of the head has emerged. If the treatment is applied later, a strobilurin + chlorothalonil mixture would be more appropriate. Cyprodinil (Unix) is best avoided at this stage for the same reasons as mentioned in the winter barley programme. Feed barley growers in Northern Ireland where quality is less of an issue and where Ramularia leaf spots are causing little damage may consider not treating the crop at this stage.

Table 3A Winter barley fungicide programme

Spray timing	Disease epidemic protected	Main fungicide	Mixing partner	Other options	Avoid
Early spring	1st peak	morpholine	Unix	triazole (DMI)* chlorothalonil**	strobilurin++
GS31-32	1st peak	Unix	strobilurin	morpholine***	triazole*
GS45-49	2nd peak	triazole (DMI)	strobilurin	chlorothalonil**	morpholine*** Unix+

Table 3B Spring barley fungicide programme

Spray timing	Disease epidemic protected	Main fungicide	Mixing partner	Other options	Avoid
Pre GS25	1st peak	-	-	chlorothalonil** morpholine***	strobilurin++
GS25-30	1st peak	Unix	strobilurin	triazole (DMI)* chlorothalonil** morpholine***	
GS45-49	2nd peak	triazole (DMI)	strobilurin	chlorothalonil**	morpholine*** Unix+

*Do not over-use triazoles in a programme to minimise sensitivity shift. A key strength of the triazole (DMI) Opus is in leaf spot protection at GS45-49

** This fungicide provides Rhynchosporium protection only. It can reduce green leaf loss from leaf spots when used at GS45-49

*** This fungicide will be essential if Rhynchosporium eradication is required, but it can cause leaves to die-back if used at GS45-49

+Unix is not compatible with common plant growth regulators, & is weak against leaf spots.

++ Strobilurin (QoI) fungicides must not be applied more than twice to any crop. This group of fungicides have greater benefit at the key timings.

Technical Detail

1. Fungicide efficacy

Introduction

It is common practice for growers to use fungicides in mixtures to manage barley diseases. Since there were concerns that some fungicides may be declining in their contribution to the control of Rhynchosporium, the first step was to determine the efficacy of individual fungicides at different doses in winter and spring barley. Once this was achieved, trials were set up where the effect of different mixtures could be determined on disease control and yields.

Materials and methods

Log dose trials

Four log dose trials were set up to assess the efficacy of fungicides when applied once to a crop. Two spring barley trials were set up in 2000 and two winter barley trials in 2001 (Table 1.1).

Table 1.1 Log dose trials

Study number	Spring / winter	Site	County	Region	Trial type	Harvest year
00487(0003)	Spring	Blairnathort	Fife	East	Log dose	2000
00487(0004)	Spring	Orwell	Fife	East	Log dose	2000
00487(0103)	Winter	Kirkton Dunfermline	Fife	East	Log dose	2001
00487(0104)	Winter	Balado Kinross	Fife	East	Log dose	2001

Each fungicide (Table 1.2) was applied as a single treatment at GS32 along a plot length of 40 metres using a log dose sprayer. The plot length was marked out into ten sections, each 4 metres in length and the dose defined as follows: 0.84, 0.69, 0.56, 0.44, 0.35, 0.27, 0.22, 0.17, 0.13, 0.1(dose). Each treatment was replicated four times. Alongside each treated plot length was an untreated buffer strip. Rhynchosporium was assessed in the buffer strip and the treated strip twice in the season, when Rhynchosporium had developed in the trial.

Table 1.2 Fungicides used in log dose trials

Number	Treatment	Full dose	Fungicide Active ingredient
1	Untreated	0	None
2	Unix	1.0 l/ha	cyprodinil
3	Corbel	1.0 l/ha	fenpropimorph
4	Torch	1.5 l/ha	spiroxamine
5	Amistar	1.0 l/ha	azoxystrobin
6	Twist	2.0 l/ha	trifloxystrobin
7	Landmark	1.0 l/ha	kresoxim methyl + epoxiconazole
8	Opus	1.0 l/ha	epoxiconazole
9	Punch C	0.8 l/ha	flusilazole + carbendazim
10	Acanto (ZA1963)	1.0 l/ha	picoxystrobin
11	Opera (BUK982)	1.5 l/ha	pyraclostrobin + epoxiconazole
12	Maneb	2.7 l/ha	maneb
13	Atlas Cropgard	2.0 l/ha	chlorothalonil
14	Unix + Twist	1.0 kg + 2.0 l/ha	cyprodinil + trifloxystrobin

Note full dose on label for Unix in barley is 0.67 kg/ha

Mixture development trials

In 2001 one spring barley trial using the susceptible variety Chariot was set up to investigate a range of mixture combinations. In 2002, four trials were set up (Table 1.3) to assess the efficacy of fungicide mixtures. The treatments applied were the same in the four trials, two of which were on spring barley and two on winter barley. Since disease pressure is higher in the winter barley crop, the mixtures could be tested under severe conditions in winter barley trials, whilst the information from the spring barley trials was a good measure of their protectant activity. The susceptible varieties of Chariot (spring barley) and Sumo (winter barley) were used for these trials.

Table 1.3 Mixture development trials

Study number	Spring / winter Variety	Site	County	Region	Trial type	Harvest year
00487(0107)	Spring (Chariot)	Bush	Midlothian	East	Mixture development	2001
00487(0206)	Spring (Chariot)	Balmonth	Fife	East	Mixture development	2002
00487(0207)	Spring (Chariot)	Islabank	Perthshire	East	Mixture development	2002
00487(0204)	Winter (Sumo)	Balmonth	Fife	East	Mixture development	2002
00487(0205)	Winter (Sumo)	Dunecht	Aberdeenshire	North	Mixture development	2002

The treatments tested in 2001 and 2002 are listed in Tables 1.4 and 1.5. The treatments were summarised by the types of active ingredient applied early and late (indicated in the mix column). Treatments were changed in 2002 to take account of results obtained in 2001.

Table 1.4 Fungicide mixtures tested in 2001 on spring barley

	GS25-30 and GS39-45	Mix
1	Nil	
2	Unix 0.5 kg/ha	U
3	Opus 0.45 l/ha	T
4	Punch c 0.4 l/ha	TM
5	Amistar 0.5 l/ha	S
6	Twist 1.0 l/ha	S
7	Unix 0.5 + Corbel 0.4	UC
8	Opus 0.5 + Corbel 0.4	TC
9	Punch C 0.4 + Corbel 0.4	TMC
10	Amistar 0.5 + Corbel 0.4	SC
11	Twist 1.0 + Corbel 0.4	SC
12	Unix 0.5 + Mycoguard 1.0	UB
13	Opus 0.5 + Mycoguard 1.0	TB
14	Punch c 0.4 + Mycoguard 1.0	TMB
15	Amistar 0.5 + Mycoguard 1.0	SB
16	Twist 1.0 + Mycoguard 1.0	SB
17	Unix 0.5 + Opus 0.5	UT
18	Unix 0.5 + Punch c 0.4	UTM
19	Unix 0.5 + Twist 1.0	US
20	Unix 0.5 + Amistar 0.5	US

Mix: T=triazole, U=Unix, S=strobilurin, C=Corbel, B=chlorothalonil, M=MBC

Table 1.5 Fungicide mixtures tested in 2002 on 2 spring barley and 2 winter barley trials

	T1 GS31-32	T2 GS45	T1 Mix	T2 Mix2
1	Nil	Nil	0	0
2	Unix 0.5	Twist 1.0	U	S
3	Opus 0.5	Opus 0.5	T	T
4	UK756 0.4	UK756 0.4	T	T
5	Unix 0.5 + Cropgard 1.0	Twist 1.0 + Cropgard 1.0	UB	SB
6	Unix 0.5 + Corbel 0.5	Twist 1.0 +Corbel 0.5	UC	SC
7	Unix 0.5 + Acanto 0.5	Opus 0.5+Acanto 0.5	US	ST
8	Unix 0.5 + Amistar 0.5	Opus 0.5+Amistar 0.5	US	ST
9	Unix 0.5 + Twist 1.0	Opus 0.5+Twist 1.0	US	ST
10	Unix 0.5 Twist 1.0	Unix 0.5 Twist 1.0	US	US
11	Unix 0.5 + Opus 0.5	Opus 0.5+Twist 1.0	UT	ST
12	Unix 0.5 + UK756 0.4 l/ha	UK958 0.75 l/ha	UT	ST
13	Opus 0.5+Twist 1.0	Opus 0.5+Twist 1.0	ST	ST
14	UK756 0.4 l/ha + Twist 1.0	UK756 0.4 l/ha + Twist 1.0	ST	ST
15	UK958 0.75 l/ha	UK958 0.75 l/ha	ST	ST
16	Opera 0.75	Opera 0.75	ST	ST
17	Unix 0.5 + Opera 0.75	Opera 0.75	UTS	ST
18	Unix 0.5 + Twist 1.0 + Corbel 0.5	Opus 0.5 + Twist 1.0	USC	ST
19	Unix 0.5 + Opus 0.5 + Corbel 0.5	Opus 0.5 + Twist 1.0	UTC	ST
20	Opus 0.5 + Twist 1.0 + Corbel 0.5	Opus 0.5 + Twist 1.0	STC	ST

Mix: T=triazole, U=Unix, S=strobilurin, C=Corbel, B=Chlorothalonil,
UK756 = HGCA3: UK958=HGCA4

Results

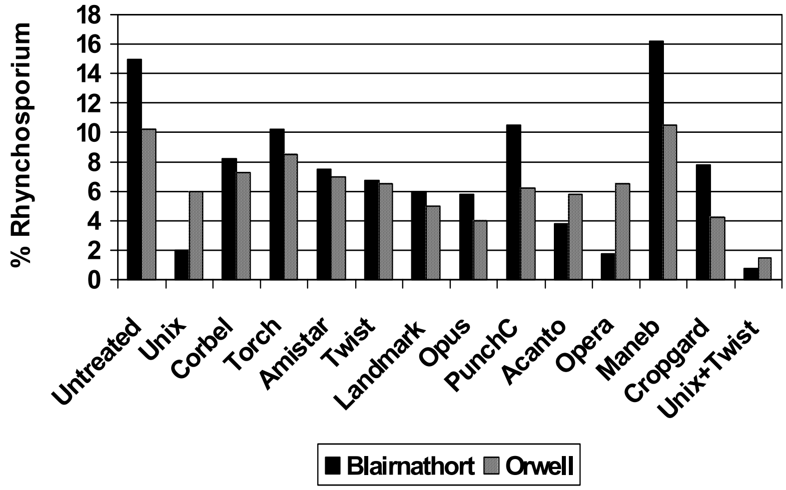
Log dose trials

Table 1.6 and Figures 1.1 and 1.2 show the Rhynchosporium levels from a key assessment in each of the log dose trials for a range of fungicides. The assessment for the winter barley trials was in May whilst the assessment taken for the spring barley trials was in late June.

Table 1.6 Percentage Rhynchosporium from full dose treatment in log dose trials

Crop	**Fungicide name and full dose (l/ha or kg/ha)**	**Spring**	**Spring**	**Winter**	**Winter**
Assessment date		30 June 00	7 July 00	5 June 01	5 June 01
Number		Blairnathort	Orwell	Kirkton	Balado
1	Untreated	15.0	10.25	14.75	13.5
2	Unix 0.67	2.0	6.0	10.5	11.0
3	Corbel 1.0	8.25	7.25	11.5	8.75
4	Torch 1.5	10.25	8.5	-	12.75
5	Amistar 1.0	7.5	7.0	13.0	5.8
6	Twist 2.0	6.75	6.5	4.3	7.5
7	Landmark 1.0	6.0	5.0	7.0	
8	Opus 1.0	5.75	4.0	8.0	13.3
9	Punch C 0.8	10.5	6.25	8.5	11.0
10	Acanto (ZA1963) 1.0	3.75	5.75	8.5	7.5
11	Opera (BUK982) 1.5	1.75	6.5	7.5	8.5
12	Maneb	16.25	10.5	-	-
13	Atlas Cropgard 2.0	7.75	4.25	7.5	6.25
14	Unix 0.67+ Twist 1.3	0.75	1.5	3.25	
*	HGCA3 + Twist	-	-	4.75	-
*	HGCA3	-	-	6.75	8.8
SED		1.712	1.080	1.4077	1.199
Sig		<.001	<.001	<.001	0.005

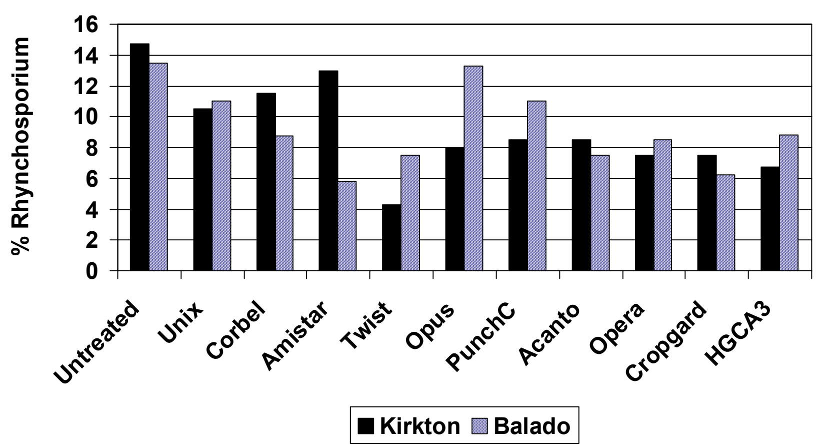
Figure 1.1 Control of Rhynchosporium using full fungicide doses in spring barley 2000



(See Table 1.6 for SEDs).

In the spring barley crop, note the poor control with Maneb (Figure 1.1). This fungicide was not used in the winter barley trials due to this poor control. Effective control was only achieved where Unix was applied with Twist, but most of the fungicides could achieve 50% control.

Figure 1.2 Control of Rhynchosporium using full fungicide doses in winter barley 2001

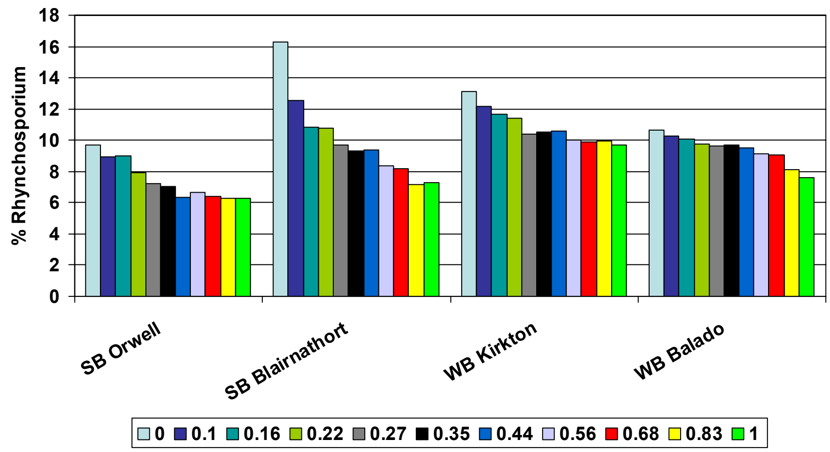


(See Table 1.6 for SEDs).

Controlling Rhynchosporium in the winter crop was more difficult, even at full doses of fungicides (Figure 1.2). Control was rarely as great as 50%, with the exception of Twist. Note too the differences in control achieved with Opus. At Kirkton it achieved good results compared to other fungicides, whilst at Balado control was poor. Unfortunately it was not possible to isolate Rhynchosporium from this site to determine the sensitivity to triazole fungicides.

The log dose trials show that achieving effective control of Rhynchosporium with a single fungicide is difficult even with a full dose. Figure 1.3 shows the dose response for the fungicides overall. Better differentiation between doses was seen in the spring crop than the winter crop, particularly at the Blairnathort site. This better control in the spring crop may be a reflection on the disease being absent at the time of treatment, whilst low levels were already present in the winter crop.

Figure 1.3 Comparison of the average dose responses in the log dose trials



(Average SED 1.349).

Looking at the winter barley site at Kirkton (Figure 1.4) it is evident that Unix alone achieved poor control. Twist achieved better control, whilst HGCA3 achieved levels of control between Unix and Twist. Good disease control was achieved where Twist was used in a mixture with Unix or HGCA3. Taking 4-5% Rhynchosporium as a definition of good control at Kirkton, this level could not be achieved through Unix or HGCA3 alone. It could be achieved using Twist alone at 1.36l/ha, but using any fungicide by itself is not good practice due to undue pressures on resistance and the fact that getting overall disease control of all potential diseases is not possible with a single active ingredient. Good control was achieved by applying Twist 1.12 l/ha + Unix 0.56kg/ha or Twist 1.12 l/ha + HGCA3 0.45 l/ha.

Figure 1.4 Dose response to specific fungicides on Winter barley at Kirkton

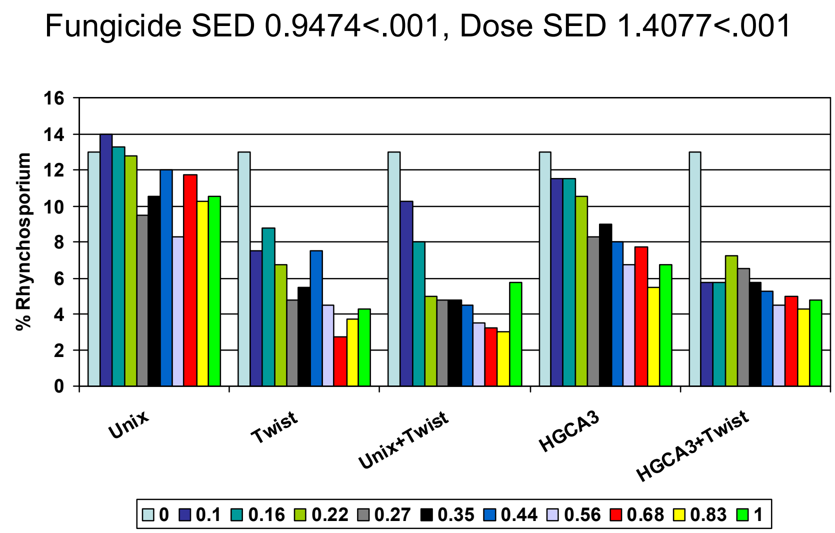
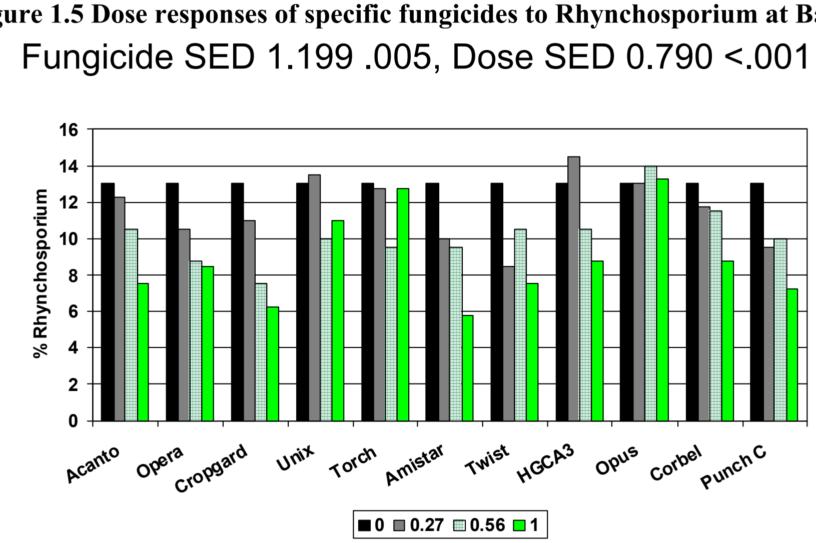


Figure 1.5 shows the dose response in winter barley at Balado for a range of common barley fungicides for a limited number of doses (nil 0, 0.22 dose, 0.56 dose and full dose 1). No single product achieved effective control of Rhynchosporium, but note the effectiveness of Cropgard. This fungicide is predominantly a protectant fungicide and that shows good long term protection, but no eradication. The fungicide Corbel is a poor Rhynchosporium fungicide, when applied alone, with a short-term eradicant effect but with no long-term protection. Hence it tended to perform poorly in these log dose trials. Although Torch is a similar fungicide to Corbel, it is less successful at eradicating Rhynchosporium.

Figure 1.5 Dose responses of specific fungicides to Rhynchosporium at Balado 2001



Mixture development

Figure 1.6 shows the development of Rhynchosporium in the one spring barley trial in 2001 and an average for two spring and two winter trials in 2002. It should be noted that in 2001 disease levels were low at the time of the first treatment but the disease developed to high levels later. In the spring trials in 2002, levels were low at the start of the season and they remained low throughout. The winter barley trials in 2002 had Rhynchosporium present at the time of the first treatment. The disease remained throughout the season but at lower levels than were seen in 2001. To achieve the most out of the treatments, further season's data would be required to test the robustness of the best fungicide treatments.

Figure 1.6 Disease levels in untreated plots in mixture development trials 2001 and 2002

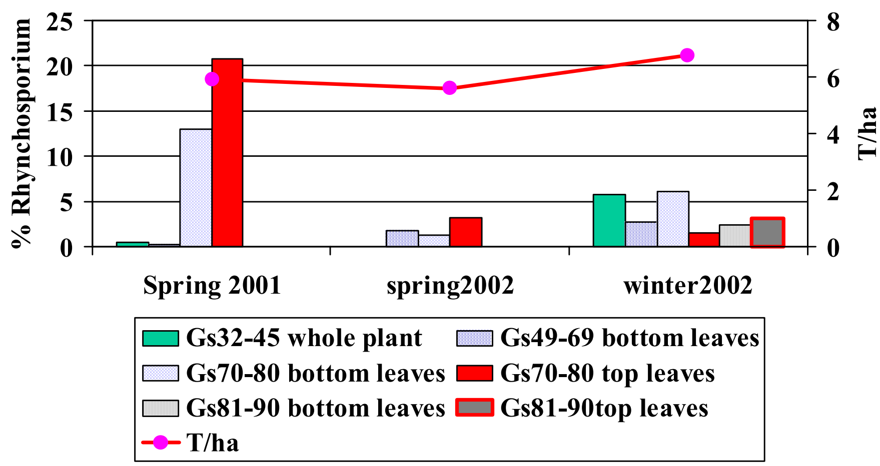


Figure 1.7 Mixture development trial on spring barley in 2001, leaf assessment late season (GS 70-80)

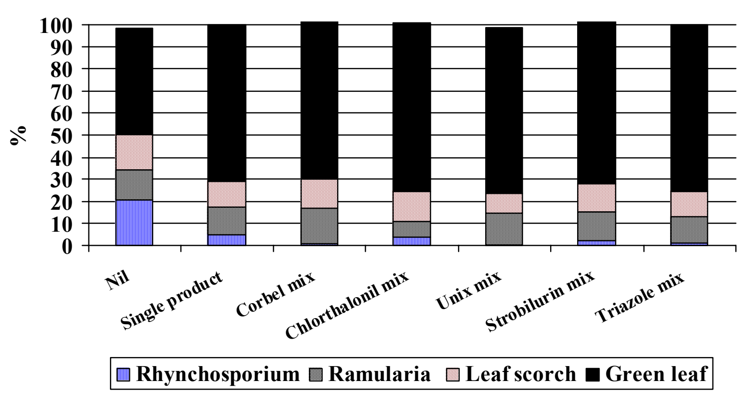


Figure 1.7 summarises the results from the single spring barley trial in 2001. It shows disease levels on the upper leaves at GS70-80 (watery ripe). Since disease was not present when the first application was made, it demonstrates the effectiveness of the product mixtures in a protectant situation. Using a single product achieved some control of Rhynchosporium, but effective control was only achievable using a two-way mixture, in which one component comprised Corbel, Unix, triazole or a strobilurin. Note chlorothalonil did provide control but was less effective than other mixtures.

Ramularia and abiotic leaf spots were present in the trial and the best reduction was seen in a mixture containing Mycoguard. Corbel mixtures and Unix mixtures had higher than average levels. Since previous research on late leaf spotting had shown similar results, it became clear that the optimum fungicide mixture may vary during the season, depending upon the disease spectrum for which control was required as well as whether disease eradication or disease protection was required.

The single trial in 2001 showed that the best mixtures used early in the season are not necessarily the best late in the season. The main reason for this is that fungicide mixtures which provide effective eradication of Rhynchosporium may exacerbate the green leaf area loss where used late in the season. Later applications therefore must achieve effective protection of Rhynchosporium and minimise the development of *Ramularia collo cygni* and abiotic leaf spots.

2002 Mixture trials

In 2002, trials were carried out on both winter and spring barley. Full results can be seen in Appendix 1. The results reported below highlight individual fungicide groups which were significantly different from other fungicides when used as components of mixtures. Differences in yield and specific weights are meaningful to a grower, but significant differences in disease levels are very small in terms of what growers would see in a field. The analysis methods applied by BioSS do however help to identify the most beneficial fungicides to use in a mixture for disease control or yield benefits.

Since Rhynchosporium was present in the winter crop at the time the first fungicide treatment was applied, the winter barley trials show which were the better fungicide mixtures for use in an eradicant situation. As disease was not present in the spring barley trials when the first fungicide was applied, the first treatment in the spring trials demonstrated the efficacy of mixtures in a protectant situation.

Yields

The two fungicides which had most impact on the yield of both winter and spring barley were the new triazole (HGCA3) which had a positive impact of 0.5 t/ha in a mixture and Chlorothalonil which had a positive impact of 0.35 t/ha in a mixture (Table 1.7). Interactions were also seen in the use of cyprodinil or morpholine in a mixture between the winter and spring crop.

Table 1.7 Impact of fungicides used in mixtures on yield

Fungicide	Impact of fungicide on yield T/ha	Probability
New triazole (HGCA3)	0.50	<.001
Chlorothalonil	0.35	0.016
Interactions cyprodinil early	0.23	0.009
Interactions morpholine late	-0.29	0.08

Cyprodinil had a greater impact on the winter barley than the spring barley. This is likely to be expected since cyprodinil (e.g. Unix) can also give eyespot control which is a greater problem in the winter crop.

There was also an interaction in the use of a morpholine (e.g. Corbel) late in the season. In the spring barley crop, this resulted in a yield lower than the untreated control (Table 1.8) This effect was common in 2002 and the use of Corbel did affect green leaf area when applied late. This was seen most on spring barley crops.

Table 1.8 Interactions of fungicide mixtures on winter and spring barley on yield (T/ha)

	Nil	Cyprodinil applied early (alone)	Morpholine applied late (with strobilurin)
Winter	6.768	7.590	7.646
Spring	5.593	5.679	5.481
SED		0.5711	0.5820

Specific weight

The new triazole fungicide and chlorothalonil all had a beneficial effect on specific weight on winter and spring barley when used as components of a mixture (Table 1.9), which was significant over other products. There is also a trend that epoxiconazole also had a beneficial effect.

Table 1.9 Impact on specific weight of fungicides used in mixtures

Fungicide	Impact of fungicide on specific weight kg/ha	Probability
New triazole (HGCA3)	1.45	<.001
Chlorothalonil	0.90	0.011
Old triazole (epoxiconazole)	0.79	0.069

Early Rhynchosporium control

Strobilurin fungicides (mean of all tested) and the new triazole fungicide had a significant impact on Rhynchosporium over other fungicides used in a mixture (Table 1.10). Note however the differences are low, but the result does indicate that a strobilurin and the new triazole were the best components to control early Rhynchosporium disease.

Table 1.10 Impact of fungicides used in mixtures on early Rhynchosporium control

Fungicide	Impact of fungicide on early Rhynchosporium %	Probability
New triazole (HGCA3)	-0.4%	0.006
Strobilurin	-0.1%	0.012

Late Rhynchosporium

The use of a morpholine, the new triazole or a strobilurin had a significant beneficial effect on late Rhynchosporium when used as components of a mixture (Table 1.11).

Table 1.11 Impact of fungicides used in mixtures on late Rhynchosporium control

Fungicide	Impact of fungicide on Rhynchosporium on upper leaves %	Probability
New triazole (HGCA3)	-0.5	<.001
Strobilurin	-0.1	0.003
Morpholine	-0.1	0.013

Ramularia top leaves

Two products achieved significantly better control of Ramularia than other products. These were the new triazole and chlorothalonil (Table 1.12)

Table 1.12 Impact of fungicides used in mixtures on Ramularia control

Fungicide	Impact of fungicide on Ramularia %	Probability
New triazole (HGCA3)	-1.2	0.007
Chlorothalonil	-3.0	<.001

Green leaf area top leaves

The new triazole (HGCA3), chlorothalonil and strobilurin were significantly better than other products in maintaining green leaf area (Table 1.13)

Table 1.13 Impact of fungicides used in mixtures on early Rhynchosporium control

Fungicide	Impact of fungicide on % Green leaf area	Probability
New triazole (HGCA3)	0.5	<.001
Chlorothalonil	0.4	<.001
Strobilurin	0.1	0.038

Discussion

No fungicide used alone achieved effective control of Rhynchosporium. Table 1.14 below shows a ranking of the products use in the four log dose trials. The message that fungicide mixtures are essential to control Rhynchosporium is clear, since all three mixtures tested in the log dose trials are at the top of the table, whilst it was rare for any individual fungicide to achieve greater than 50% control.

Table 1.14 Ranking of products used alone at full dose to control Rhynchosporium

Fungicide name & dose (l/ha or kg/ha)	Fungicide type	Mixture(M) or Single product (S)	Average Rhynchosporium	% Control
Unix 0.67+ Twist 1.3	Unix + Strobilurin	M	1.8	86%
Landmark 1.0	Triazole + Strobilurin	M	4.5	66%
Opera 1.5	Triazole + Strobilurin	M	6.1	55%
Twist 2.0	Strobilurin	S	6.3	53%
Acanto 1.0	Strobilurin	S	6.4	52%
Atlas Cropgard 2.0	Chlorothalonil	S	6.4	52%
Unix 0.67	Unix	S	7.4	44%
HGCA 3 0.8	Triazole	S	7.8	41%
Opus 1.0	Triazole	S	7.8	41%
Amistar 1.0	Strobilurin	S	8.3	38%
Corbel 1.0	Morpholine	S	8.9	33%
Punch C 0.8	Triazole + MBC	M	9.0	32%
Torch 1.5	Spiroxamine	S	10.5	22%
Maneb	Dithiocarbamate	S	13.4	0%
Untreated	-	-	13.3	-

Planning trials to determine the most effective mixtures is not straight forward since the needs of controlling disease early may not be the same as those needed for late control. A single trial in 2001 demonstrated that effective control of Rhynchosporium was not enough by itself. Some mixtures gave good control early in the season, but using the same mixture later gave poor yield responses due to the presence of other factors, including Ramularia and green leaf area loss.

Before conclusions are reached from the four trials done in 2002, it must be emphasised that this is a single season's data and the best mixtures for that season may not be best over several seasons. It should also be noted that disease levels may be higher in other seasons and this may affect the performance of specific mixtures. The innovative methods of statistical analyses used did however come up with some useful guides to mixtures. The new triazole fungicide HGCA3 provides a step forward in yields. The same fungicides also increased specific weight and it also achieved significantly better control of Rhynchosporium and Ramularia when used in mixture. As a consequence it also achieved significantly higher green leaf area. Since this product is a triazole, lessons from the rest of this project must be learnt, since it is important the product is not allowed to slide in its effectiveness through over use. Chlorothalonil also achieved a good yield increase when used in a mixture and this helped increase specific weights. The advantage of chlorothalonil over other fungicides used in a mixture were in Ramularia control and green leaf area retention.

Strobilurin fungicides were highlighted as amongst the best when used in mixture for Rhynchosporium control, but they were not the most effective as far as yield or green leaf area is concerned. This trend is of concern, since these two features were the key strengths of strobilurin fungicides when they were first introduced.

The morpholine fungicide fenpropimorph has a useful benefit in controlling Rhynchosporium, but some negative effects were also seen. It appeared to have an influence in mixture on Rhynchosporium, but it also appeared to have a negative effect on the spring barley yield, which resulted in a yield lower than the untreated. This effect has been seen before, particularly where it is applied to spring barley late in the season and may result from a loss in green leaf area.

Finally cyprodinil also showed an interaction in that it was more beneficial when applied to winter barley than spring barley. Cyprodinil shows activity against a range of diseases, particularly eyespot. This disease is more common in winter cereal than spring cereals so this may explain why it was more beneficial in the winter crop.

The methods used in 2002 make a useful foundation for future work which should be done over several seasons and sites. Any future mixture research is likely to require a factorial approach making use of statistical designs for mixture experiments instead of the limited combinations used in this study, in order to ensure a range of effective mixtures can be determined.

2 Varietal Resistance & fungicide timing

Introduction

Variety resistance scores are published for current winter and spring barley varieties on the Recommended List (published by CEL Limited) based on a 1-9 scale where a low number represents greater susceptibility to the disease (Table 2.1). Looking at the scores for winter barley, it could be assumed that the majority of varieties show good resistance to Rhynchosporium.

Table 2.1 Rhynchosporium susceptibility to winter and spring barley (Recommended List 2003)

Winter barley Varieties	Resistance rating	Spring barley varieties	Resistance rating
Pearl	8	Cocktail	5
Kestrel	8	Troon	5
Regina	7	Cellar	5
Vanessa	8	Prestige	5
Fanfare	8	Optic	4
Diamond	7	Chalice	5
Leonie	9	Decanter	5
Cannock	8	Spire	5
Carat	7	Kirsty	5
Scylla	6	Static	5
Haka	5	Riviera	5
Sumo	5		
Opal	8		
Antonia	8		
Pastoral	7		
Jewel	8		
Heligan	7		
Vertige	5		
Siberia	7		
Sequel	8		
Pict	8		
Angela	8		
Muscat	8		

In the field, Rhynchosporium is currently the major disease affecting winter crops, particularly early in the season.

Materials and methods

Field trials

Eleven field trials were set up in different regions in Scotland and Northern Ireland (Table 2.2). Six were based on spring barley varieties with different Rhynchosporium ratings and five on winter barley varieties. Table 2.3 shows the varieties used and their resistance rating scores to Rhynchosporium.

Table 2.2 Field trials on influence of barley variety and fungicide timing on development of Rhynchosporium

Study number	Spring / winter	Site	County	Region	Trial type	Harvest year
00487(0001)	Spring	Annan Dumfriesshire	Dumfries	West	Variety x timing	2000
00487(0002)	Spring	Tibbermore	Perthshire	East	Variety x timing	2000
00487(03Belfast)	Spring	Crossnacreevy	N Ireland	NI	Variety x Timing	2000
00487(0105)	Spring	Annan	Dumfries	West	Variety x timing	2001
00487(0106)	Spring	Tibbermore	Perthshire	East	Variety x timing	2001
00487(01Belfast)	Spring	Crossnacreevy	N Ireland	NI	Variety x timing	2001
00487(0101)	Winter	Tibbermore	Perthshire	East	Variety x timing	2001
00487(0102)	Winter	Bush	Midlothian	East	Variety x timing	2001
00487(0201)	Winter	Bush	Midlothian	East	Variety x timing	2002
00487(0202)	Winter	Annan	Dumfries	West	Variety x timing	2002
00487(0203)	Winter	Crossnacreevy	N Ireland	NI	Variety x timing	2002

Table 2.3 Barley varieties used in field trials

Winter barley varieties	Rhynchosporium resistance rating	Spring barley varieties	Rhynchosporium resistance rating
Sumo	5	Chariot	4
Intro	6	Optic	4
Siberia	7	Riviera	5
Pastoral	7	Landlord	6
Jackpot	8	Century	8
Leonie	9	Pewter	8

The varieties received fungicide treatments (Table 2.4) which were aimed to effectively control Rhynchosporium and powdery mildew early in the season or late in the season. They should not be seen as examples of cost effective treatments.

Table 2.4 Fungicide Treatments

Winter barley	**GS25-30 (Early)**	**GS31-32 (Early)**	**GS39-45 (Late)**
Nil	Nil	Nil	Nil
Full	Unix 0.3 + Corbel 0.3	Unix 0.5 + Twist 1.0	Unix 0.5 + Twist 1.0 + Corbel 0.3
Early only	Unix 0.3 + Corbel 0.3	Unix 0.5 + Twist 1.0	Nil
Late only	Nil	Nil	Unix 0.5 + Twist 1.0 + Corbel 0.3
Spring barley	**GS25-30 (Early)**		**GS39-45 (Late)**
Nil	Fortress 0.1		Fortress 0.1
Full	Unix 0.67 + Amistar pro 2.0 + Fortress 0.1		Unix 0.67 + Amistar pro 2.0 + Fortress 0.1
Early only	Unix 0.67 + Amistar pro 2.0 + Fortress 0.1		Fortress 0.1
Late only	Fortress 0.1		Unix 0.67 + Amistar pro 2.0 + Fortress 0.1

Doses in litres or Kg/hectare

Variety Trials

Permission was granted from CEL Limited and the BSPB to use field data from variety trials from 1996 – 2001. Data from CEL was from trials in the north of Britain, whilst BSPB data was from the whole of the UK. All the data available on Rhynchosporium from variety trials over this six year period was analysed using varieties which were on the Recommended list (RL) from 2000 up to 2002. Rhynchosporium levels on susceptible varieties, including Sumo (winter) and Optic (spring) were used to categorise the data into low disease pressure and high disease pressure sites. Where data existed for different growth stages, it was categorised into very early growth stages (up to GS32), early growth stages (GS32 - GS45), middle growth stages (GS49-69) and late growth stages (GS 70 onwards). Table 2.5 and 2.6 show the number of sites appropriate for each category.

Recommended list data comprise percentage disease which were transformed log10 (percentage+1) The results were back transformed to percentage disease. BSPB data was on a 1-9 scale where 1 = low disease and 9 high disease. This data was not transformed. It was analysed separately from the RL data.

Table 2.5 Number of sites used for each growth stage and disease pressure category in winter barley

	Total		**Up toGS32**		**GS32-GS45**		**GS49-69**		**>GS70**	
	BSPB	RL	BSPB	RL	BSPB	RL	BSPB	RL	BSPB	RL
High disease pressure site	8	45	0	3	1	3	2	10	5	29
Low disease pressure site	14	31	0	5	0	4	4	10	10	12

BSPB – BSPB data, RL Recommended list data

Table 2.6 Number of sites used for each growth stage and disease pressure category in spring barley

	Total		**Up toGS32**		**GS32-GS45**		**GS49-69**		**>GS70**	
	BSPB	RL	BSPB	RL	BSPB	RL	BSPB	RL	BSPB	RL
High disease pressure site	7	42	0	0	0	2	3	11	4	29
Low disease pressure site	6	59	0	1	0	10	3	24	3	24

BSPB – BSPB data, RL Recommended list data

The amount of data for the early growth stages was too limited to make precise conclusions on the varietal resistance at growth stages before GS45. This situation would be expected for spring barley since it is usual for Rhynchosporium to develop beyond these growth stages. It was unfortunate for the winter barley since the early epidemic of Rhynchosporium occurred on the lower leaves up to boot stage growth stages. The RL and BSPB data can only be used to determine the resistance ratings of the second later epidemic.

Results

Spring barley

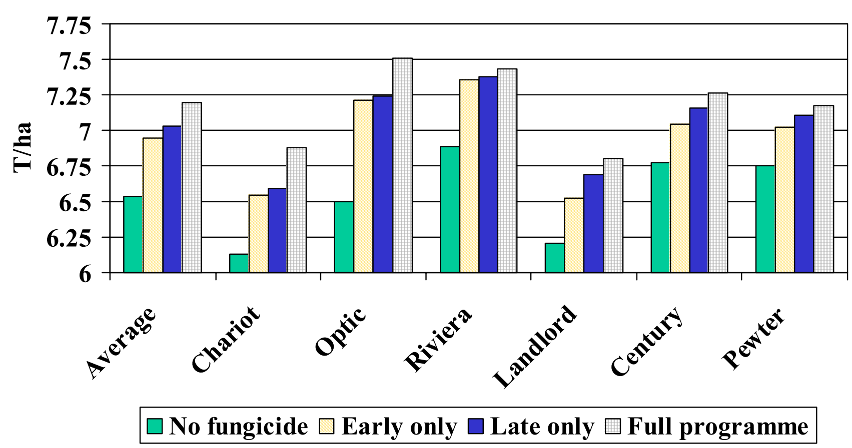
Yields

Over the two seasons of trials, the best yield was achieved with two fungicide treatments for both resistant and susceptible varieties. Overall the early treatment was as important as the late treatment to achieve a good yield, but with the more resistant varieties (Century and Pewter), the later treatment appeared to be more important than the early treatment to achieve the best yield (Table 2.7 and Figure 2.1).

Table 2.7 Spring barley yields (Tonnes/hectare)

Variety	Rhynchosporium resistance rating	No fungicide	Early only	Late only	Full programme
Chariot	4	6.126	6.549	6.594	6.882
Optic	4	6.499	7.209	7.246	7.510
Riviera	5	6.888	7.353	7.378	7.43
Landlord	6	6.207	6.520	6.690	6.805
Century	8	6.775	7.046	7.158	7.267
Pewter	8	6.752	7.022	7.103	7.173
Average		**6.541**	**6.950**	**7.027**	**7.197**
SED “Average” 0.0907					
Degrees of freedom (Df) 97					
Sig variety <.001					
Sig timing <.001					

Figure 2.1 Spring barley yields



Specific weights

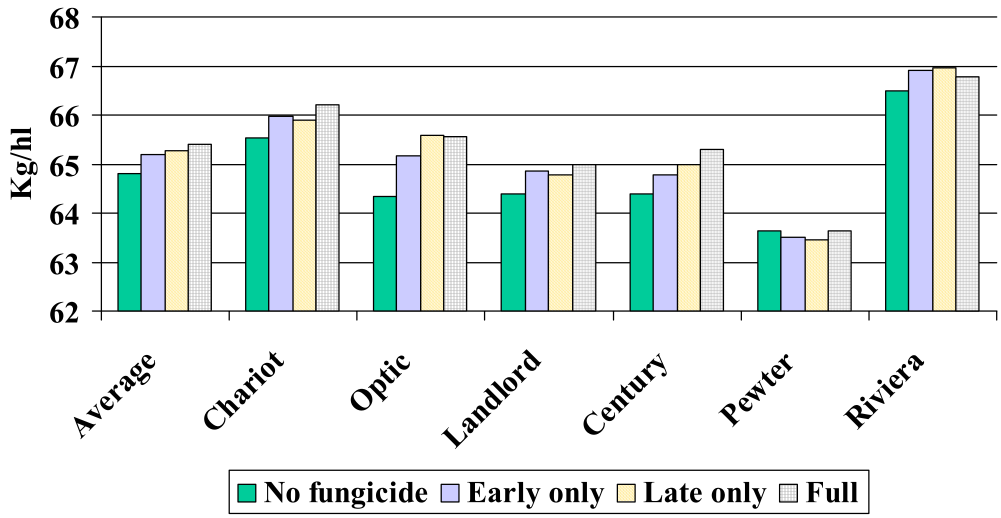
Specific weights were influenced most by the variety and fungicide treatment had little effect on average (Table 2.8 and Figure 2.2). All the varieties except Riviera achieved the best specific weight with a two spray programmes. Although screenings were not measured as part of this trial, other research has shown that in 2002, fungicides significantly reduced screenings levels when applied twice.

Overall grain prices have dropped over the last 5 years, which makes premiums for grain quality very important. Where a quality premium makes a large difference to the price (e.g. malting barley premiums), the full programmes will be the most cost effective. Where quality premiums are not an issue, there may be more scope for growers to reduce fungicide costs, if the grower is prepared to accept a potentially reduced yield as well as poor quality.

Table 2.8 Specific weights (kg/hl)

Variety	**Resistance rating**	**No fungicide**	**Early only**	**Late only**	**Early and late**
Chariot	4	65.527	65.982	65.905	66.200
Optic	4	64.345	65.173	65.577	65.564
Landlord	5	64.400	64.864	64.791	64.982
Century	6	64.395	64.777	64.977	65.291
Pewter	8	63.632	63.500	63.464	63.641
Riviera	8	66.491	66.909	66.964	66.791
Average		**64.798**	**65.201**	**65.282**	**65.411**
SED Average 0.1932					
Df 97					
Sig variety <.001					
Sig Timing ns					

Figure 2.2 Specific weights kg/hl



Disease

Table 2.9 shows the development of Rhynchosporium in untreated spring barley. When the first fungicide was applied at GS25-30, Rhynchosporium was either absent or present at low levels even in the most susceptible varieties

Table 2.9 Development of Rhynchosporium during season on upper and lower leaves

Variety	Rating	GS32	GS32-45	GS49-69 bottom	GS49-69 top	GS70-80 bottom	GS70-80 top	GS81-90 top	GS81-90 bottom
Chariot	4	0.1	0.7	2.4	1.2	0.6	6.7	4.3	0.6
Optic	4	0.1	1.4	4.4	2.2	0.8	6.0	7.9	0.8
Riviera	5	0.0	0.4	1.4	0.4	1.7	2.0	5.2	1.7
Landlord	6	0.0	0.4	1.6	0.8	0.2	1.6	3.3	0.2
Century	8	0.0	0.0	0.2	0.1	0.0	0.0	0.0	0.0
Pewter	8	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Average		**0.0**	**0.4**	**1.3**	**0.6**	**0.5**	**1.8**	**2.3**	**0.5**
SED		0.176	0.075	0.115	0.077	0.172	0.122	0.176	0.169
Df		97	97	97	97	96	97	74	51
Sig		0.05	<.001	<.001	<.001	<.001	<.001	<.001	.017

Figure 2.3 shows the development of Rhynchosporium in Optic (a susceptible variety) and the average of all the six varieties based on two years data. Disease levels are low up to GS32 and the disease then starts to develop on the lower leaves up to boot stage (GS49). As the lower

leaves dieback, disease levels drop, but it then develops to greater levels on the upper leaves during the later growth stages. Optic shows a similar pattern to the average, with two peaks of Rhynchosporium seen on the lower leaves at GS49-69 and on the upper leaves at GS81-90. If variety trials are to be assessed to determine their susceptibility to disease in the field, timing of the assessment is important to determine an accurate measure of the susceptibility of a variety. For fungicides to be effective, it is important they are applied before disease is present since current fungicides show poor eradicant activity (see section1). Fungicides must also protect the crop during the two peaks of development. This is only achievable by applying two fungicides. The first applied before disease develops to protect the lower leaves and the second aimed to protect the upper leaves.

Figure 2.3 Development of Rhynchosporium in Optic

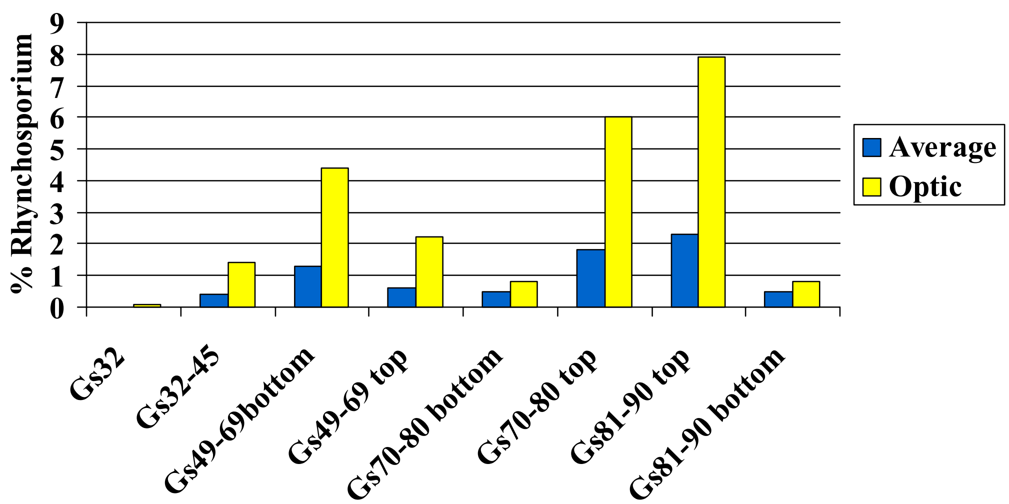
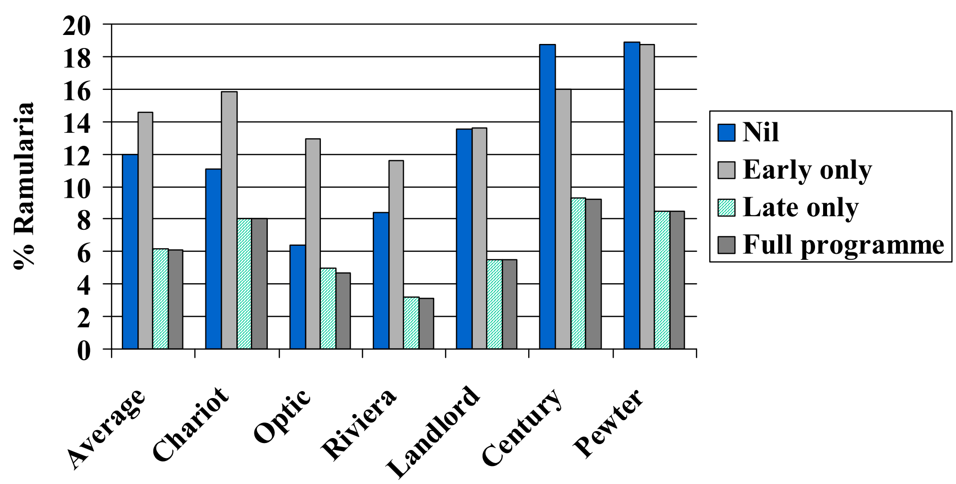


Table 2.10 and Figure 2.4 show disease levels on the upper leaves at GS81-90 (when disease levels were at their highest). Although the two spray programmes achieved the best control, it was the early fungicide, which achieved the better control of the single spray programme for the most susceptible varieties Chariot, Optic and Riviera. Disease levels in the more resistant varieties (Century and Pewter) were low in all treatments. However, all varieties responded to the fungicides as far as yield is concerned (see Table 2.7).

Table 2.10 Spring barley % Rhynchosporium at GS81-90 on the top leaves

Variety	Rhynchosporium resistance rating	No fungicide	Early only	Late only	Full programme
Chariot	4	4.3	0.2	1.7	0.0
Optic	4	7.9	1.0	1.8	0.0
Riviera	5	5.2	0.3	1.2	0.4
Landlord	6	3.3	0.1	1.1	0.0
Century	8	0.0	0.2	0.0	0.1
Pewter	8	0.1	0.1	0.1	0.0
Average		**2.3**	**0.8**	**0.3**	**0.1**
SED variety x fungicide timing 0.382					
Df 74					
SED “Average “0.440					
Sig variety <.001					
Sig timing <.001					

Figure 2.4 Influence of fungicide timings on Rhynchosporium at GS81-90 in spring barley



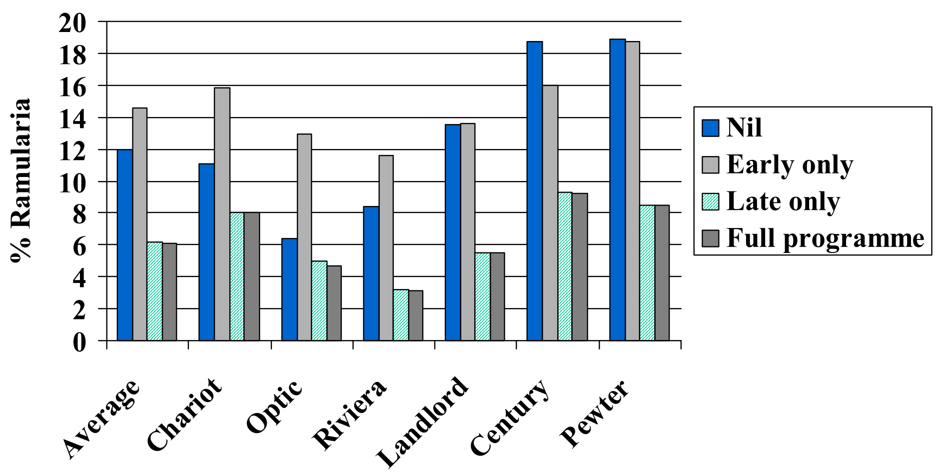
Ramularia barley leaf spots

The presence of Ramularia and abiotic barley leaf spots may explain why Rhynchosporium resistant varieties responded well to fungicide treatments. Although the fungicides were not specifically designed to control barley leaf spots, differences were seen between the varieties and the fungicide treatments.

Table 2.11 % Ramularia on upper leaves GS 81-90

Variety	Rhynchosporium resistance rating	No fungicide	Early only	Late only	Full programme
Chariot	4	11.1	15.8	8.0	8.0
Optic	4	6.4	12.9	5.0	4.7
Riviera	5	8.4	11.6	3.2	3.1
Landlord	6	13.5	13.6	5.5	5.5
Century	8	18.7	16.0	9.3	9.2
Pewter	8	18.9	18.7	8.5	8.5
Average		**12.0**	**14.6**	**6.2**	**6.1**
SED Variety x timing 0.330					
Df 51					
SED "Average" 0.125					
Df average 7					
Sig Variety <.001					
Sig Timing ns					

Figure 2.5 % Ramularia levels at GS81-90 on the upper leaves



The early fungicide had no effect on Ramularia, which typically develops on the upper leaves after flowering. The GS45-49 fungicide in the two spray programme achieved good control and this control was similar to that achieved from the late fungicide only. Chariot, Century and Pewter were affected most from Ramularia and Riviera was affected the least. If varieties can be bred with effective resistance to Rhynchosporium, but have only poor resistance to Ramularia, it may be possible to treat varieties once late in the season. Varieties susceptible to Rhynchosporium, which are either susceptible or resistant to Ramularia, will require two fungicide treatments to effectively control both diseases.

Table 2.12 Abiotic leaf spots on upper leaves GS 81-90

Variety	Rhynchosporium resistance rating	No fungicide	Early only	Late only	Full programme
Chariot	4	0.3	6.7	4.0	6.5
Optic	4	0.0	0.6	0.2	0.1
Riviera	5	0.2	0.0	0.0	0.0
Landlord	6	0.8	0.8	2.8	3.6
Century	8	0.0	0.0	0.2	0.1
Pewter	8	0.4	0.0	0.0	0.0
Average		**0.5**	**0.5**	**0.8**	**0.8**
SED variety x timing 0.383					
Df 51					
SED "Average" 0.141					
Df 51					
Sig Variety <.001					
Sig timing ns					

Abiotic leaf spots were generally low in all the varieties except Chariot.

Winter barley

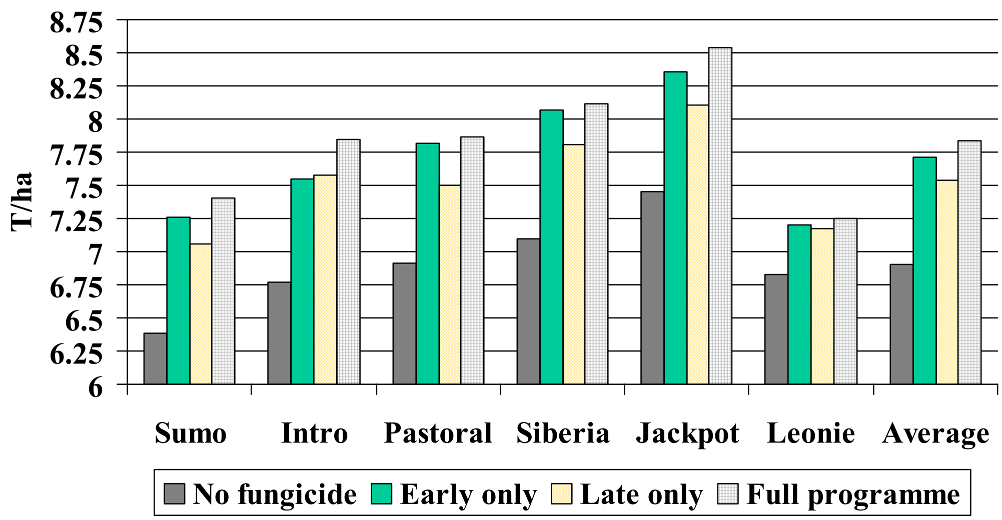
Yields

Winter barley yields are recorded in Tables 2.13 and Figure 2.6. All the varieties responded to fungicide, including the Rhynchosporium resistant variety Leonie. Overall early fungicide treatments contributed more to the yield than the later fungicide treatment.

Table 2.13 Winter barley yields

Variety	Rhynchosporium resistance rating	No fungicide	Early only	Late only	Full programme
Sumo	5	6.386	7.256	7.061	7.403
Intro	6	6.765	7.551	7.578	7.845
Pastoral	7	6.910	7.818	7.499	7.865
Siberia	7	7.100	8.070	7.804	8.116
Jackpot	8	7.455	8.360	8.103	8.542
Leonie	9	6.828	7.205	7.169	7.249
Average		**6.907**	**7.710**	**7.536**	**7.837**
SED variety	0.1459				
Sig variety	<.001				
Df	74				
SED timing	0.1191				
Sig timing	<.004				
Df	74				

Figure 2.6 Winter barley yields in tonnes/hectare



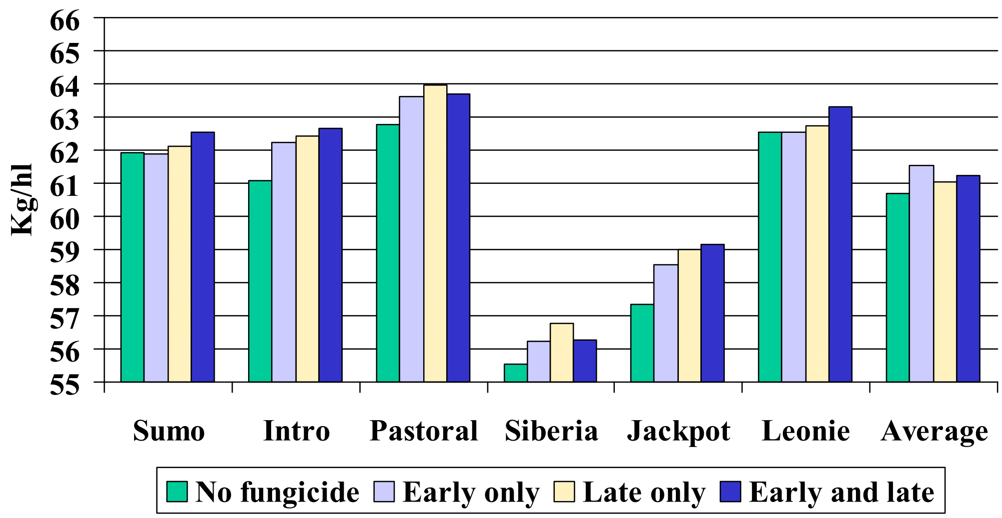
Specific weights kg/hl

Specific weights are reported in Table 2.14 and Figure 2.7. With the exception of the six-row variety Siberia and the two row variety Pastoral, the full spray programme achieved the best specific weights.

Table 2.14 Specific weights in winter barley

Variety	Rhynchosporium resistance rating	No fungicide	Early only	Late only	Early and late
Sumo	5	61.921	61.879	62.132	62.542
Intro	6	61.068	62.237	62.437	62.663
Pastoral	7	62.774	63.611	63.947	63.700
Siberia	7	55.547	56.226	56.768	56.258
Jackpot	8	57.353	58.542	58.995	59.158
Leonie	9	62.553	62.537	62.747	63.289
Average		**60.687**	**61.521**	**61.054**	**61.220**
SED variety	0.7318				
Sig variety	<.001				
Df	74				
SED timing	0.5975				
Sig timing	Ns				
Df	74				

Figure 2.7 Winter barley specific weights



Disease

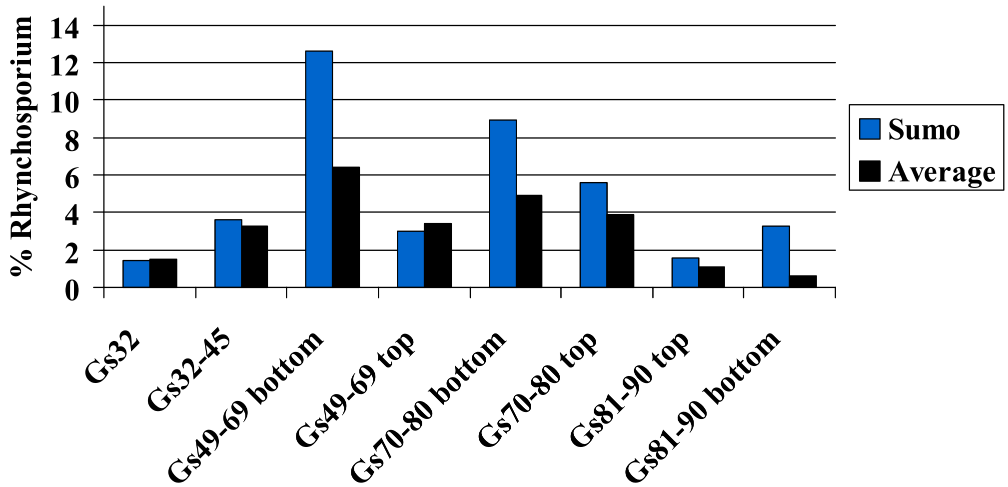
The development of disease was recorded in the untreated varieties throughout the season. The results are seen in Table 2.15.

Table 2.15 Development of Rhynchosporium during season on winter barley upper and lower leaves (untreated)

Variety	**Rating**	**GS32**	**GS32-45**	**GS49-69 bottom**	**GS49-69 top**	**GS70-80 bottom**	**GS70-80 top**	**GS81-90 top**	**GS81-90 bottom**
Sumo	5	1.4	3.6	12.6	3.0	8.9	5.6	1.6	3.3
Intro	6	1.6	4.9	8.4	6.8	8.5	8.3	2.7	0.6
Pastoral	7	2.2	5.9	13.1	4.2	3.9	5.3	1.6	0.0
Siberia	7	1.8	3.7	13.7	5.6	8.8	4.4	0.8	0.9
Jackpot	8	1.3	3.1	4.1	2.9	7.4	3.0	0.8	0.4
Leonie	9	0.8	0.8	0.2	0.7	0.2	0.7	0.0	0.0
Average		**1.5**	**3.3**	**6.4**	**3.4**	**4.9**	**3.9**	**1.1**	**0.6**
SED		0.172	0.216	0.274	0.199	0.213	0.219	0.235	0.146
Sig		0.008	<.001	<.001	0.001	<.001	0.01	0.03	Ns
Df		74	74	23	74	51	74	51	5

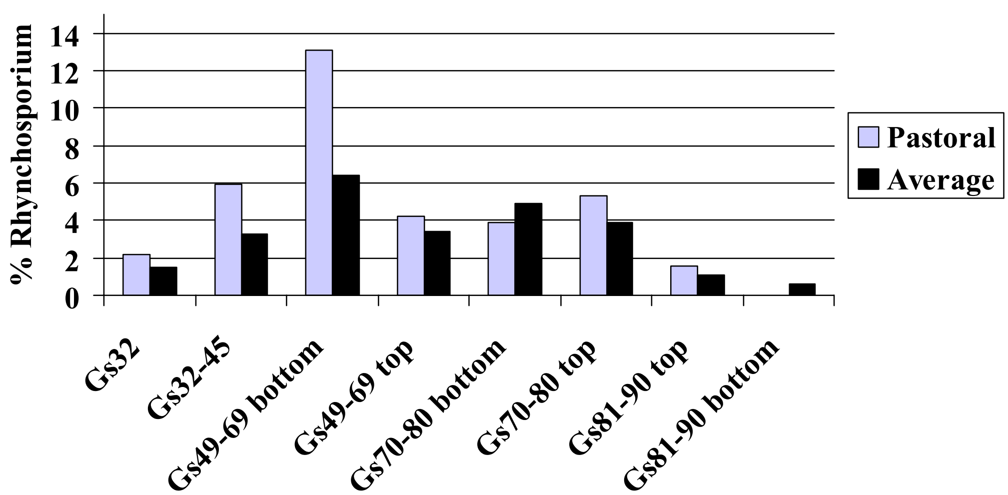
Sumo is a susceptible variety to Rhynchosporium and the development of the disease is seen in Figure 2.8 compared to the average. Disease was established at GS32 and levels increased to the highest levels at GS49-69 on the lower leaves. Rhynchosporium continued to be seen throughout the rest of the season at levels, which were above the average. The information suggests it is correct to define Sumo as a susceptible variety to Rhynchosporium and assessing the crop at most stages through the season would confirm this.

Figure 2.8 Development of Rhynchosporium in the susceptible variety Sumo



Pastoral has a resistance rating of 7, but consistently shows high disease levels in the north of Britain. Figure 2.9 shows the development of Rhynchosporium compared to the average. Rhynchosporium was established at GS32 and it increased to a maximum on the lower leaves at GS49-69. At later stages of growth, Rhynchosporium levels were similar to the average. This information suggests that if assessments were carried out on the lower leaves at GS49-69, the resistance rating for Pastoral would be lower than the current rating of 7. Taking assessment data later in the season would give the variety a higher rating for Rhynchosporium resistance.

Figure 2.9 Development of Rhynchosporium in Pastoral

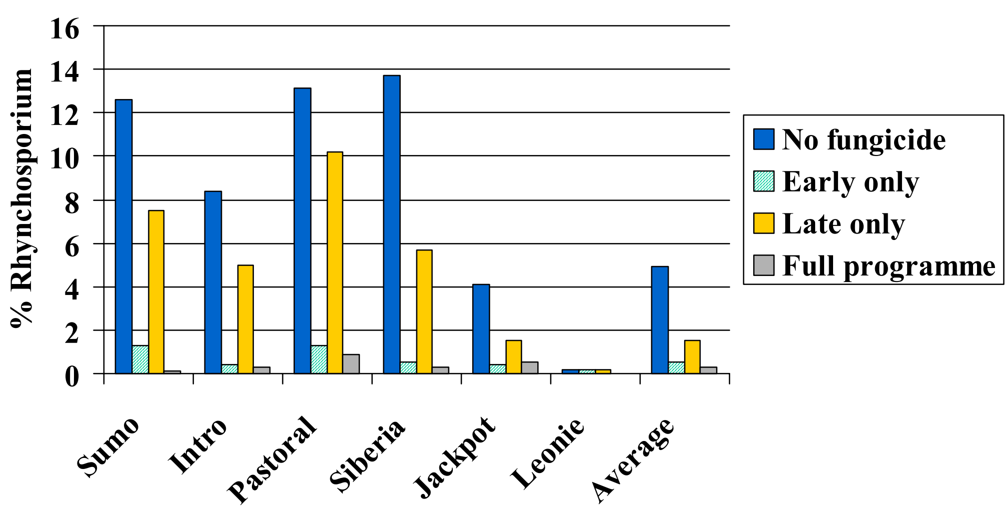


Since Rhynchosporium levels were greatest on the lower leaves at GS49-69 on all the varieties, the effectiveness of the fungicide treatments was compared at this time (see Table 2.16 and Figure 2.10).

Table 2.16 Winter barley % Rhynchosporium at GS49-69 on the lower leaves

Variety	Rhynchosporium resistance rating	No fungicide	Early only	Late only	Full programme
Sumo	5	12.6	1.3	7.5	0.1
Intro	6	8.4	0.4	5.0	0.3
Pastoral	7	13.1	1.3	10.2	0.9
Siberia	7	13.7	0.5	5.7	0.3
Jackpot	8	4.1	0.4	1.5	0.5
Leonie	9	0.2	0.2	0.2	0.0
Average		**4.9**	**0.5**	**1.5**	**0.3**
SED variety	0.273				
Sig variety	<.001				
DF variety	23				
SED timing	0.218				
Sig timing	0.004				
Df timing	23				

Figure 2.10 Winter barley % Rhynchosporium at GS49-69 on the lower leaves



The full spray programme achieved the best control of Rhynchosporium in all varieties. The early treatment achieved good control, whilst the later treatment alone was less effective. This is probably not surprising since in most situations the late treatment would be applied when

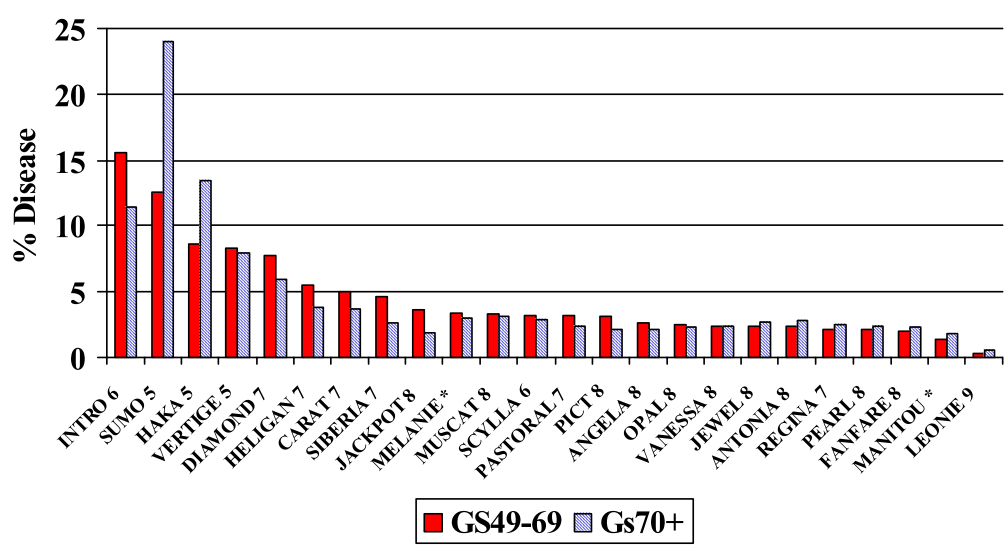
Rhynchosporium levels are at their greatest in the crop. Note that Siberia and Pastoral achieved higher levels of Rhynchosporium on the lower leaves at this growth stage than the more susceptible varieties (according to current variety resistance ratings) Sumo and Intro. The more resistant varieties Jackpot and Leonie have disease levels in keeping with their current variety resistance ratings. During the period of this research, Ramularia and abiotic barley leaf spots were becoming a higher priority to control in winter barley. If they become a regular occurrence in the winter crop, the yield response to the later fungicide will become more significant.

CEL and BSPB data

CEL Recommended list data

Levels of Rhynchosporium on current Recommended list varieties and varieties used in this study can be seen in Figure 2.11 (sorted by growth stage of the assessment) and Figure 2.12 (sorted by high and low disease pressure trials). Similar data for spring barley varieties based on the same scale as the winter barley data are given in Figure 2.13 (sorted by growth stage of the assessment) and Figure 2.14 (sorted by high and low disease pressure trials).

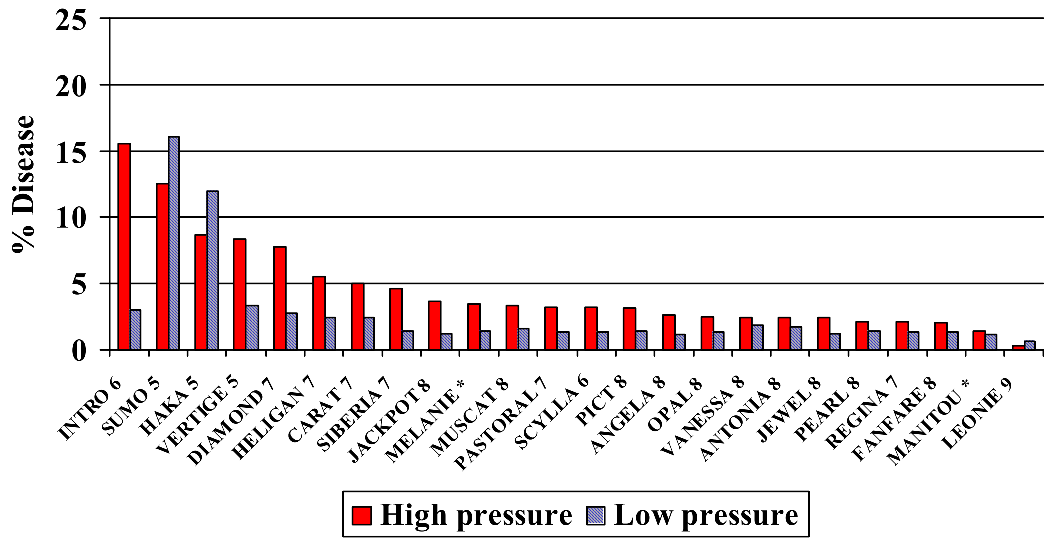
Figure 2.11 Percentage Rhynchosporium on RL winter varieties at GS45-69 and GS70+



SED 3.153

The numbers next to the variety name is the variety resistance rating (based on 1-9 scale where 1 = susceptible and 9 resistant to Rhynchosporium). Figure 2.11 shows Intro, Sumo and Haka to be the most susceptible varieties and Leonie the most resistant. Assessing trials at GS45-60 or GS70+ makes little difference to the overall disease rating and for most varieties there is more disease at the GS49-69 time, except two of the most susceptible varieties Sumo and Haka where Rhynchosporium continued to develop.

Figure 2.12 % Rhynchosporium on RL winter varieties at high and low disease pressure sites

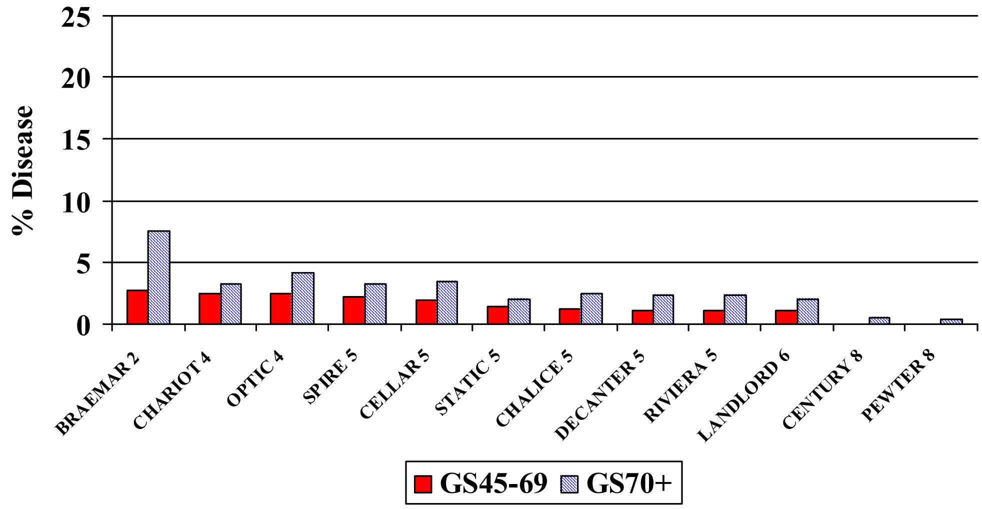


SED 0.153

Figure 2.12 shows disease scores where sites have been selected as high or low disease pressure. Taking the high disease pressure information, there is more differentiation between varieties, which are currently categorised with resistant ratings of 6, 7 and 8 than from data taken from the low disease pressure sites.

Sumo and Haka had high disease levels in both situations, but in contrast, Intro had lower disease levels in the sites where the Rhynchosporium pressure was low.

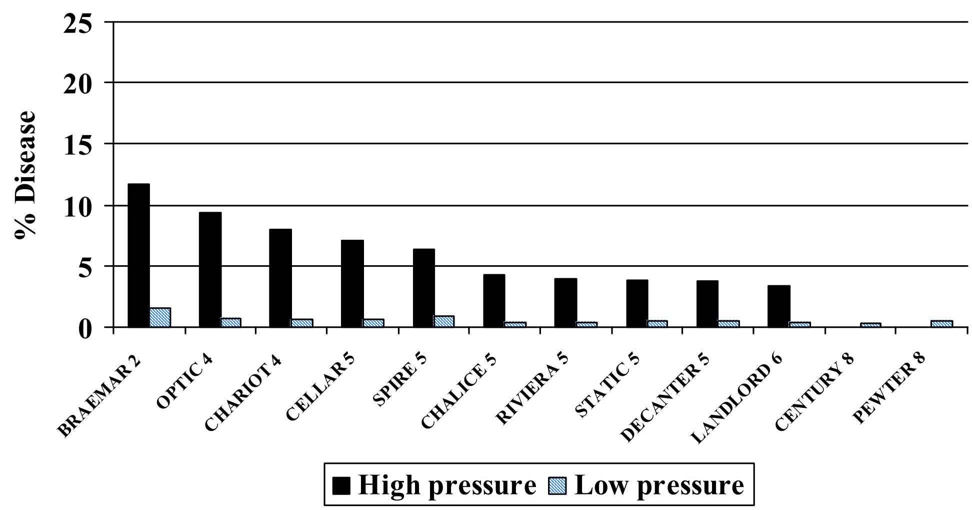
Figure 2.13 % Rhynchosporium on RL spring varieties at GS45-69 and GS70+



SED 5.190

Data for spring barley trials defined by growth stage (Figure 2.13) are on the same scale as the winter varieties (Figure 2.11). Disease levels are generally higher at the later growth stages and the relative order agrees with the resistance rating. The most susceptible spring barley variety Braemar, average 8% Rhynchosporium at GS70+ and has a resistance rating of 2. Winter barley varieties with higher or similar disease levels (e.g. Sumo, Intro, Haka, and Vertige) have resistance ratings of 5, 6 or 7. This suggests that disease standards for the winter crop are different to the spring crop for a specific resistance rating.

Figure 2.14 % Rhynchosporium on RL spring varieties at high and low disease pressure sites



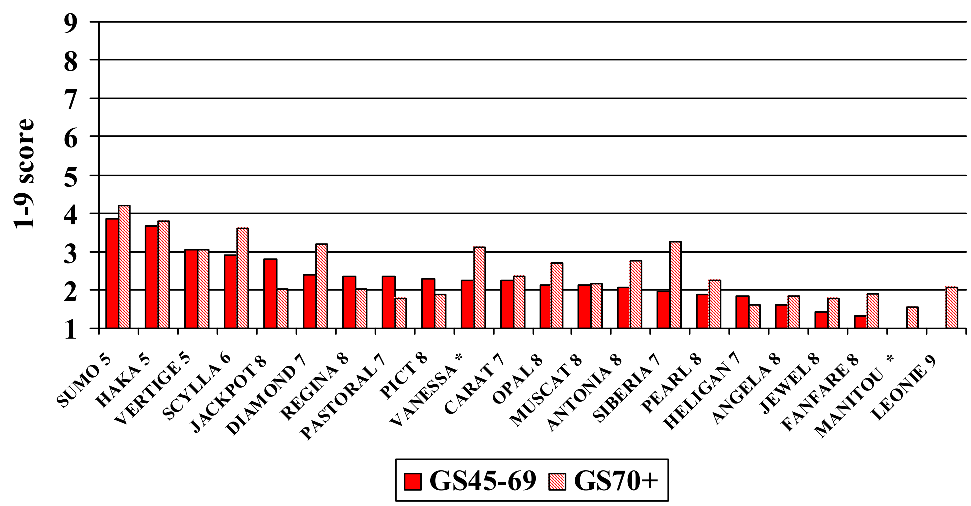
SED 5.190

Splitting trials between high and low disease pressure sites (Figure 2.14 shows that current resistance ratings are in agreement with disease levels seen under high disease pressure situations. All the varieties had similar disease levels in the low disease pressure sites Even at the high disease pressure sites, there is little parity between the scores for the spring crop with the winter crop.

BSPB Recommended list data

The BSPB data was split in the same categories as the CEL data, by disease pressure and growth stage. The disease scoring is done on a 1-9 scale where 1 = low disease and 9 the highest. The score next to the variety is the resistance rating score where 1 = susceptible and 9 resistant.

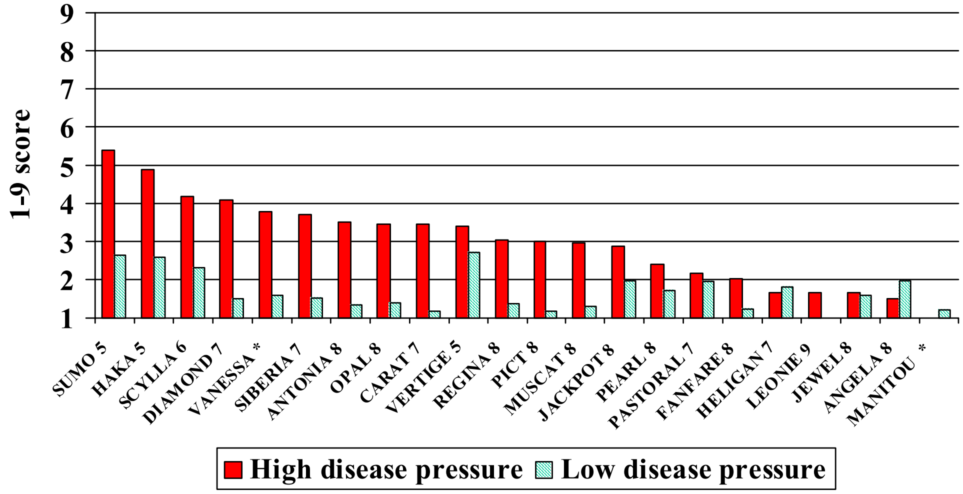
Figure 2.15 Rhynchosporium on RL winter varieties at GS45-69 and GS70+



SED 0.8026

Disease levels were similar at the two growth stage bands, but disease levels were generally higher at the later growth stages, with the exception of Jackpot and Pastoral. Varieties with resistance ratings of 5 had the highest levels of disease, but there was variability between varieties with resistance ratings of 6-9.

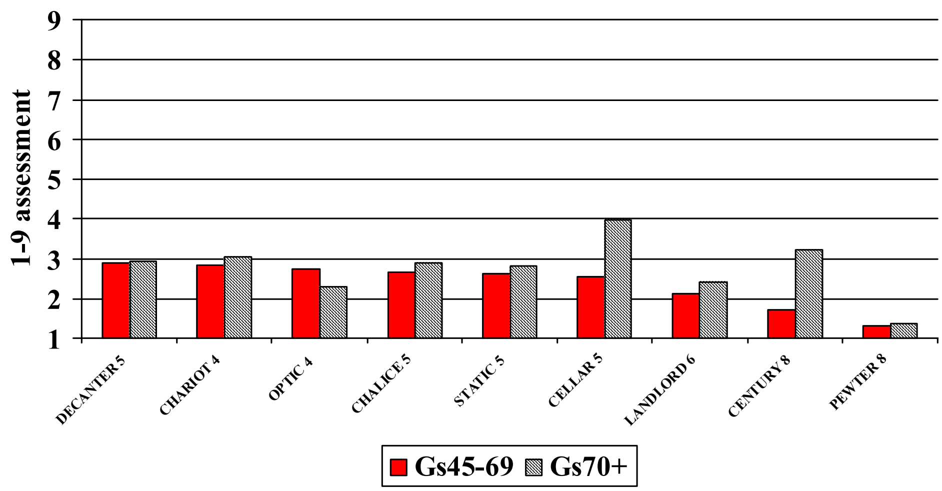
Figure 2.16 Rhynchosporium on RL Winter varieties at high and low disease pressure sites



SED 0.7708

Sumo and Haka achieved the highest disease levels and they amongst the most susceptible varieties. Leonie had a low disease score and this variety is one of the most resistant varieties. Disease levels on varieties with resistance ratings of 6 - 8 were very similar at high disease pressure sites.

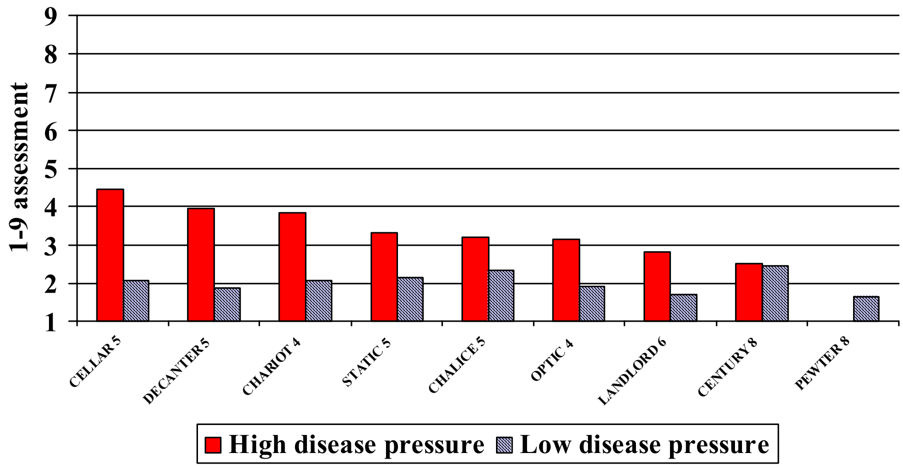
Figure 2.17 Rhynchosporium on RL spring varieties at GS45-69 and GS70+



SED 0.9440

Disease levels were higher at the later growth stages, particularly on Cellar and Century. Pewter achieved a low disease level at both growth stage bands which was in agreement with the varieties resistance rating.

Figure 2.18 Rhynchosporium on RL spring varieties at high and low disease pressure sites



SED 0.5323

The higher disease sites gave a better differentiation of the varieties, but is was difficult to differentiate between varieties with a resistance rating of 4 or 5.

When comparing the scores for winter and spring barley varieties, for a given amount of Rhynchosporium, a winter barley variety had a higher resistance rating than a spring barley variety.

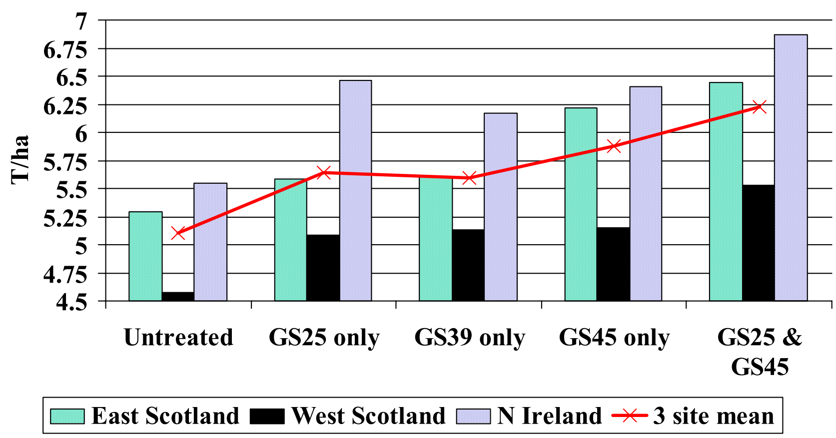
There is a good case to re-grade winter barley varieties to match the spring barley ratings. This may give winter varieties which currently have ratings of 5 a lower score. It is likely that some winter varieties currently with scores of 7 and 8 will also drop, leaving only the consistently better varieties with ratings of 7 or higher. Selecting high disease pressure sites on the basis of data from known susceptible varieties will help to identify differences in the varieties which currently have ratings of 7 or 8. Since assessments used to determine resistance ratings are predominantly at the end of the season, it still does not resolve problems with Pastoral which tend to get more disease in the first peak of disease on the lower leaves at GS45, but which tend to get lower disease levels later in the season.

Timing of a single treatment in a susceptible spring barley

Three spring barley trials carried out in 2002 in the East of Scotland, West of Scotland and Northern Ireland provided a good opportunity to look at differences in fungicide timings over a single season. Figure 2.19 shows the individual yields at the three sites and the average yield, where a fungicide treatment was applied either once or twice at different timings. The treatment applied at GS25 was Unix 0.5kg/ha + Opus 0.5 l/ha whilst Twist 1.0 l/ha + Opus 0.5 l/ha was applied either at GS39 or GS45.

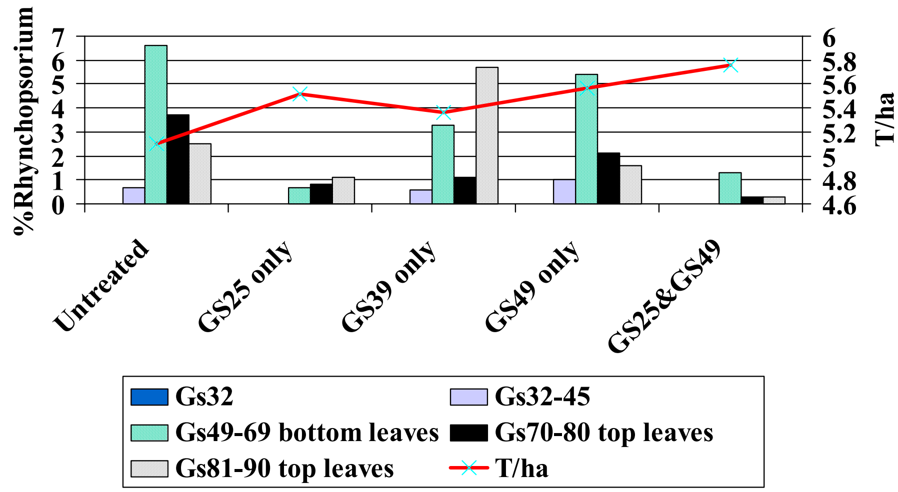
The key difference was in the overall yields, but there was a trend towards the best yields coming from the later fungicide timing and the two spray programme. A single treatment timing at GS39 did not achieve the best yield. However, leaving a crop untreated until boot stage is not a practical option to growers in most seasons, since Rhynchosporium would be present in the crop at that time and effective eradication is difficult.

Figure 2.19 Yields from different fungicide timing trials in different regions in 2002



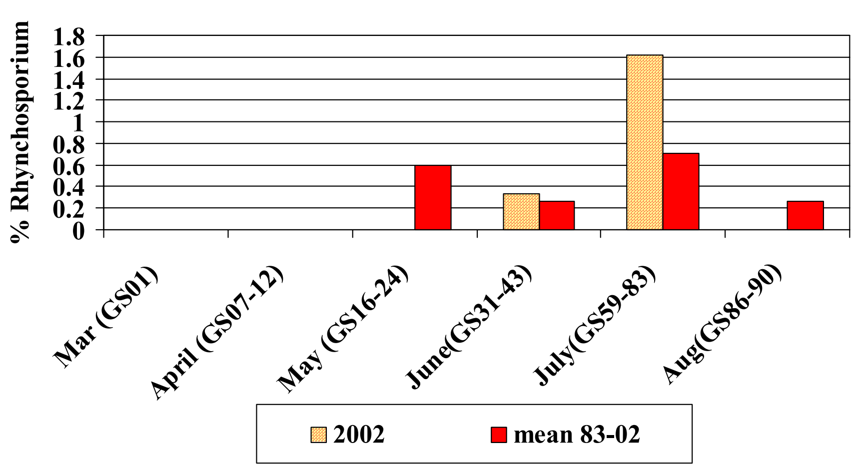
Looking at the development of Rhynchosporium based on an average of the three trials, (Figure 2.20), Rhynchosporium was not present up to GS32. A fungicide applied earlier at GS25 gave effective control through the season however. Leaving the first treatment until GS39 delayed disease development on the upper leaves at GS70-80, but the disease took hold again later on. Leaving the first treatment until GS45 achieved some control on the upper leaves. The best option for both disease control and yields was an early fungicide treatment and a late fungicide treatment. This approach achieved effective disease control and also achieved the best yields. In Northern Ireland, the single treatment which gave the best yield response was at GS25. If quality of the grain is less of an issue and barley leaf spots (i.e. Ramularia) remain low in this region, growers in Northern Ireland may wish to consider a single treatment only. Growers requiring a quality premium or growers in areas where Ramularia causes extensive damage later in the season require two treatments for the best economic response.

Figure 2.20 Development of Rhynchosporium following a single or 2 spray fungicide programme



SAC monitors commercial crops and the average levels of disease in 2002 and the overall mean based on data from 1983- 2001 can be seen in Figure 2.21. Rhynchosporium levels are low since many crops would have received fungicides to control the disease. It does however show that Rhynchosporium levels were below average during March, April and May and above average in July. Given this pattern of disease development, it is not surprising the later treatment achieved good yields, since the disease pressure was high late in the season, but it does show that even in a season where disease levels are lower than average at the start of the season, the importance of the GS25 fungicide treatment.

Figure 2.21 'Adopt a Crop' data showing Rhynchosporium levels in commercial crops



Discussion

Spring barley variety resistance ratings

The resistance ratings of the spring barley varieties under test appeared to mirror the severity of Rhynchosporium seen in the field. Although Rhynchosporium developed in two peaks throughout the season on spring barley, the second peak continued until late into the season. A late assessment of Recommended List trials anytime after GS45 would achieve acceptable data to determine an accurate field resistance ratings.

Spring barley disease control

These two peaks of disease in spring barley help to demonstrate why it is difficult to treat spring barley once for effective all season control of Rhynchosporium. The early fungicide helps to keep disease out up to boot stage whilst a boot stage fungicide continues the protection for the rest of the season. If a single treatment is applied, it is best to apply it early before the disease is established. Unfortunately this approach will have no effect on controlling barley leaf spots later in the season. A single treatment in the middle of the season will have missed the early peak of disease and growers run the risk of trying to eradicate Rhynchosporium, which is, not straightforward with the current fungicides available. This timing is also too early to control Ramularia and other barley leaf spots. For this disease, it was the later treatment, which achieved the best control. The early fungicide did not influence disease levels on the upper leaves. In order to get the best control of all diseases in the spring barley crop, the optimum is to apply an early fungicide to protect the crop from Rhynchosporium up to boot stage. A further fungicide treatment is required at boot stage to continue the protection of the crop against Rhynchosporium and to protect against Ramularia.

Winter barley variety resistance ratings

In the winter barley crop, Rhynchosporium was present throughout the season. There were peaks on the lower leaves at GS49-69 and on the upper leaves at G70-80. For some varieties (e.g. Pastoral and Siberia), the early peak was the most significant and disease levels were lower on the top leaves. Most assessments to determine resistance ratings for winter barley are done at growth stages later than GS45-69. They are therefore a good measure of the second epidemic. Since assessments for variety trials are also based on plot assessments, it is possible that varieties with high disease levels earlier in the season would have lost many of the lower leaves and as such these leaves would not be scored in the assessment. As a result of this, some susceptible varieties may show lower disease levels in a late assessment and therefore be given a high disease resistance rating. Assessing the lower leaves at GS49-69, ignoring the healthy upper leaves which have yet to become infected, would provide a more accurate score for varieties susceptibility to Rhynchosporium of this first peak of disease.

Parity between spring and winter barley variety resistance ratings

Looking at the severity of disease in winter and spring barley variety trials, disease levels are generally higher on winter barley varieties, but the disease resistance scores of recommended list varieties are also higher. To ensure parity between the resistance ratings of winter and spring barley varieties, it is suggested that the resistance ratings for the most susceptible winter varieties should be lowered from 5 down to 3. This would allow varieties currently with scores of 7 or 8 to be spread out to more realistic resistance scores ranging from 5 to 8. Leaving resistance scores 7-9 for varieties which consistently show low levels of disease in high disease pressure situations will give growers more confidence in the Rhynchosporium disease rating.

Winter barley disease control

Controlling Rhynchosporium in winter barley with fungicides is more difficult than for the spring crop since the disease is present at significant levels before fungicides are applied. Early treatments before GS32 can help to check the disease and provide more manageable levels of Rhynchosporium at the GS31-32 treatment timing. Later in the season, Rhynchosporium does develop on the upper leaves, but during the period of this research, levels did not reach the peak seen earlier in the season. Where barley leaf spots do become a common occurrence in the winter crop, the importance of the later treatment will increase.

SAC has monitored commercial crops for disease throughout the season since 1983. Table 2.17 shows the disease progress. Disease levels are higher in the winter crop than the spring crop. With winter barley it is common for the disease to be present early in the spring and the disease peaks in April and May. In recent years, there has also been a second peak of disease in June or July. Spring barley crops generally show little disease in March and April the disease peaks in May and July.

Knowledge of the seasonal patterns of Rhynchosporium is helpful to the grower in predicting when the disease is likely to reach a peak and can also help produce more accurate scores for resistance ratings. An understanding of within-season variation in varietal differences is also useful in varietal selection. Assessments taken when the disease peaks will provide a more accurate picture of varietal resistance.

Table 2.17 Average % Rhynchosporium disease in commercial winter and spring barley crops in Scotland 1983-2002 compared with disease levels in last three seasons

	Winter barley				Spring Barley			
	2000	**2001**	**2002**	**Average %**	**2000**	**2001**	**2002**	**Average %**
January	0.1	0.1	-	0.1	-	-	-	-
February	2.5	0.6	-	0.9	-	-	-	-
March	1.7	1.4	1.4	1.1	0.0	-	-	0.0
April	3.3	2.9	2.1	3.0	0.0	0.0	0.0	0.0
May	1.9	2.7	2.0	2.3	0.0	0.0	0.0	0.6
June	2.0	0.5	1.4	1.6	0.6	0.1	0.3	0.3
July	1.4	0.0	2.9	1.4	1.7	0.1	1.6	0.7
August	-	-	-	-	0.6	0.1	0.0	0.3
September	0.0	-	-	0.0	-	-	-	-
October	0.0	-	-	0.0	-	-	-	-
November	0.0	-	-	0.0	-	-	-	-
December	0.0	-	-	0.0	-	-	-	-

3 Fungicide sensitivity

Introduction

In 1999, there were concerns from growers in Scotland growing winter barley continuously or in short rotations that epoxiconazole was providing poor control of Rhynchosporium. Previous HGCA-funded research demonstrated that in the majority of trials, Demethylation inhibitor (DMI) sensitivity of *Rhynchosporium secalis* isolates was lower after two half-rate applications of epoxiconazole. Although there was no consistent difference in effects on epoxiconazole sensitivity between three partner fungicides (fenpropimorph, cyprodinil or azoxystrobin), all tended to reduce selection for resistance compared with two half-rate applications of epoxiconazole alone. It was concluded that selection for DMI resistance is continuing to occur in *R. secalis*, but that use of a partner fungicide helps to slow down the process, while not preventing it. (Cooke & Locke,2002).

The poor field performance observed by growers highlighted the need to investigate the sensitivity of Rhynchosporium to epoxiconazole further and also to investigate its sensitivity to other fungicide groups to ensure that by avoiding use of DMI fungicides, or limiting their use to control Rhynchosporium, no undue resistance pressure was being placed on other fungicide groups. Sensitivity testing was carried out for the DMI fungicides epoxiconazole and flusilazole, the anilinopyrimidine cyprodinil, the QoI azoxystrobin and the benzimidazole carbendazim.

Materials and methods

Samples were taken from trials in previous sections (five in 2000 and seven in 2001) and also from three specific trials set up in 2002 (Table 3.1). Leaf samples were taken prior to any fungicide applications and later in the season following one or two applications of fungicide, where possible collecting 100 lesions per plot to optimise isolate numbers.

Immediately after collection, leaves were allowed to air-dry and then refrigerated. After transportation to the testing laboratory they were stored at –12°C.

For isolation, mature lesions were cut from leaf pieces (up to 50 lesions per sample to yield 5-6 isolates), surface-sterilised and plated onto iprodione-amended malt yeast glucose agar plates (10 mg iprodione l^{-1}). During incubation (18°C), lesions were examined regularly and *R. secalis* growth picked off onto antibiotic Czapek Dox agar amended with mycological protein. This procedure was repeated over a 3 week period to ensure that slower-growing isolates were also obtained. Clean *R. secalis* isolates were put into long-term storage as agar plugs in sterile distilled water at 5°C prior to testing.

For assays, spore suspensions were prepared by picking off spores from actively growing *R. secalis* cultures into bottles containing glucose, yeast medium (10 ml) amended with 100 μg ml^{-1} chloramphenicol. Suspensions were stored at 4°C overnight before testing.

Epoxiconazole sensitivity assay

Tests were carried out in 96-well microplates to which a series of concentrations of technical grade epoxiconazole (supplied by BASF) was added. Spore suspensions of the test isolates in growth medium were added to the wells. Each isolate was tested in duplicate against 30, 10, 3.33, 1.11, 0.37, 0.123, 0.041 and 0 mg epoxiconazole l^{-1}. Plates were incubated (covered and sealed with parafilm) at 18°C for 14-21 days in darkness then growth of *R. secalis* was assessed by measuring the absorbance at 450 nm. The Minimum Inhibitory Concentration (MIC), defined as the concentration of epoxiconazole which prevented >90% growth, was determined for each isolate by checking absorbance data against visible growth in wells.

Flusilazole sensitivity assay

Testing was carried out as for epoxiconazole, except that flusilazole (as 'Sanction'; technical grade flusilazole was not available) was used. The test concentrations were 30, 10, 3.33, 1.11, 0.37, 0.123, 0.041 and 0 mg flusilazole l^{-1}.

Cyprodinil sensitivity assay

Cyprodinil sensitivity testing was carried out on selected isolates for years 2000 and 2001 only using modifications of two methods supplied by Syngenta. Year 2000 isolates were tested using 25 compartment Petri dishes and amended agar. Year 2001 isolates were tested using 96-well microplates and amended liquid media.

<u>Year 2000 isolates</u>: Yeast malt agar (YMA) was amended with technical grade cyprodinil (supplied by Syngenta) to achieve final concentrations of 10, 1, 0.1, 0.01, 0.001, 0.0001 and 0 mg cyprodinil l^{-1} and dispensed into 25-well Petri plates. Each well containing amended agar was inoculated with a spore suspension of the appropriate test isolate; isolates were replicated four times on each plate and tested on duplicate plates of each concentration. After incubation (18°C, 7-10 days), the area and density of fungal growth on each well was assessed. Minimum inhibitory concentration (MIC) values were determined by comparison with growth on the untreated control.

Year 2001 isolates: Glucose/gelatin medium was amended with technical grade cyprodinil (supplied by Syngenta) dissolved in acetone. Cyprodinil-amended medium was added to microplate wells to give final concentrations of 10, 1, 0.1, 0.01, 0.001 and 0 mg cyprodinil l^{-1} after addition of spore suspensions of the test isolates. Each isolate was tested in duplicate. Plates were incubated and MIC values determined as for epoxiconazole.

Azoxystrobin sensitivity assay

Spore suspensions (600 µl) of test isolates were added to each well of 25-well Petri plates. Alkyl ester broth (1.4 ml), amended with technical grade azoxystrobin (supplied by Syngenta) to achieve final concentrations of 10, 5, 1, 0.5 and 0 mg azoxystrobin l^{-1}, was carefully pipetted into each well. Each isolate was tested on three replicate plates. After incubation (10 days, 19°C with gentle rocking), wells were assessed for presence or absence of growth and the MIC (the lowest concentration inhibiting all growth) value determined for each isolate.

Carbendazim sensitivity assay

YMA amended with technical grade carbendazim to give final concentrations of 25, 10, 1 and 0 mg carbendazim l^{-1} was dispensed into 90 mm Petri plates and inoculated with 10 µl aliquots of spore suspensions of the test isolates. Each isolate was tested on three replicate plates of each concentration. After incubation (18°C, 10 days), growth was assessed and MIC values for each isolate determined.

Presentation of sensitivity data

Results from the isolates are presented either as average MIC values or as the percentage of isolates within specific MIC classes.

Table 3.1 Sensitivity field trials in 2002

Trial study number	Spring / winter	Site	County	Region	Trial type	Harvest year
00487(0208)	Spring	Bush Midlothian	Midlothian	East	Sensitivity testing	2002
00487(0209)	Spring	Belfast	Belfast	NI	Sensitivity testing	2002
00487(0210)	Spring	Annan Dumfriesshire	Dumfries	West	Sensitivity testing	2002

Results

Changes in the sensitivity of Rhynchosporium to triazole fungicides (epoxiconazole)

Table 3.2 and Figures 3.1 and 3.2 show the changes in sensitivity of Rhynchosporium to epoxiconazole over several seasons in Scotland and Northern Ireland. There was an indication that Rhynchosporium was more sensitive to epoxiconazole in Northern Ireland than Scotland, but as fewer isolates Northern Ireland were tested, this may not be significant. There was also a difference in sensitivity over the years, and between sites within a year. In 2001 and 2002, some Rhynchosporium isolates were not controlled by epoxiconazole at concentrations greater than 30 mg/l for the first time. It can be concluded therefore that Rhynchosporium is becoming progressively less sensitive to epoxiconazole (i.e. requiring a higher dose to achieve effective disease control). There is an indication of a bimodal pattern developing with the first peak at 0.04 mg/l and the second peak at 3.33-10 mg/l. Prediction of the sites where Rhynchosporium isolates were less sensitive to epoxiconazole was unreliable, particularly in 2000 and 2001, but in 2002, there was greater consistency towards all sites in Scotland showing a greater number of isolates more resistant to epoxiconazole. It can no longer be assumed therefore that it is only intensive barley sites which are most likely to have the least sensitive isolates.

In Scotland in 2001 at each site a substantial proportion of isolates fell into the most sensitive category (ranging from 31-82%, depending on site); these should be effectively controlled by epoxiconazole in the field. However, many isolates required very much higher doses to inhibit their growth and this may be reflected in less effective disease control. By 2002, only 20% of isolates were in the most sensitive category leaving 80% which would require higher doses of epoxiconazole to control them.

Table 3.2 Sensitivity of Rhynchosporium isolates to epoxiconazole 1998-2002*

Year	Site	Total	% isolates in each category							
		no.	MIC category (mg epoxiconazole/l^{-1})							
		tested	0.04	0.12	0.37	1.11	3.33	10	30	>30
1998*	N Ireland	312	36.0	30.0	4.0	21.0	5.0	4.0	0.0	0.0
2000	N Ireland	39	15.4	10.3	17.9	17.9	20.5	17.9	0.0	0.0
2000	Scotland	186	10.2	11.8	15.6	17.7	22.0	17.7	4.8	0.0
2001	Scotland	213	46.6	9.4	5.5	9.4	15.3	7.4	5.5	0.9
2002	N Ireland	26	34.6	0.0	7.6	23.1	19.2	15.3	0.0	0.0
2002	Scotland	376	22.6	5.3	16.7	27.1	17.0	6.4	2.9	1.9

* data from 1998 (from Project 1181) included for comparison

Figure 3.1 Sensitivity to epoxiconazole, percentage isolates from Scotland within each minimum inhibitory concentration category 2000-2002

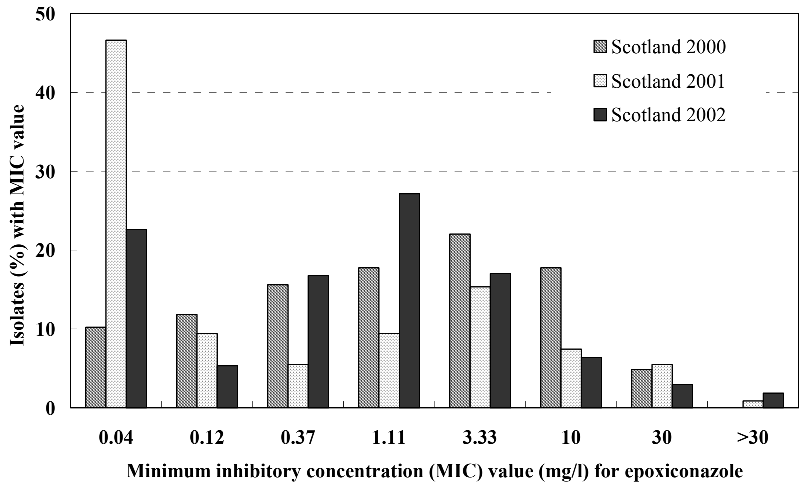
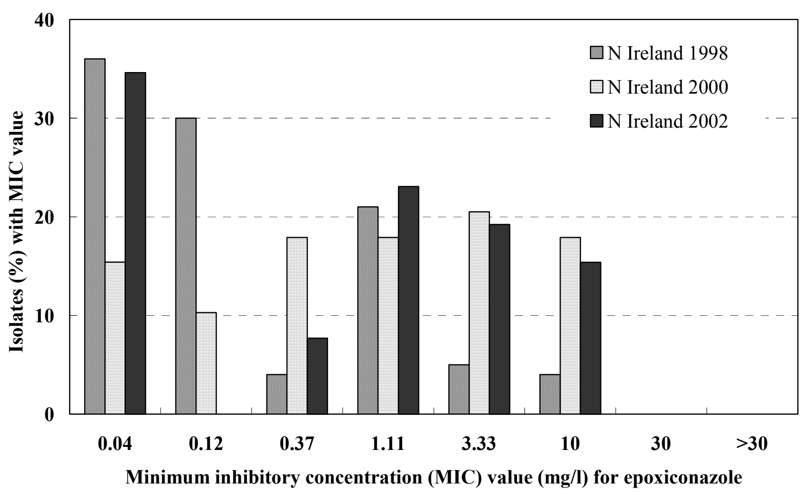


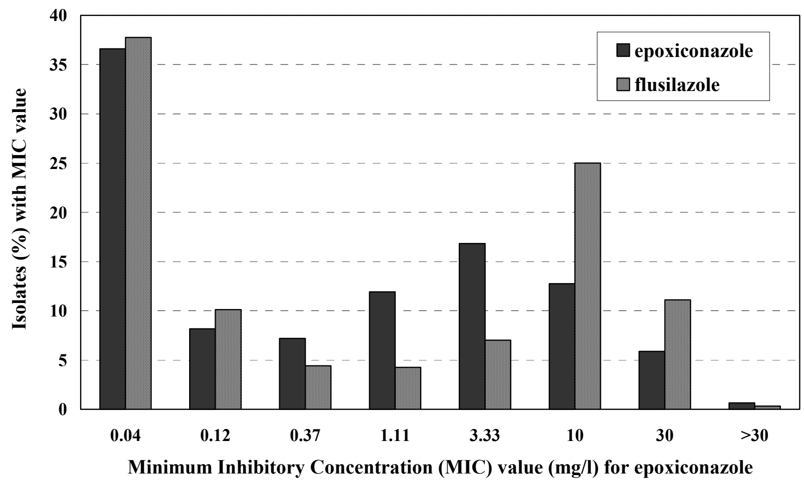
Figure 3.2 Sensitivity to epoxiconazole, percentage isolates from Northern Ireland within each minimum inhibitory concentration category



Changes in the sensitivity of Rhynchosporium to triazole fungicides (flusilazole)

Figure 3.3 compares the sensitivity of flusilazole with epoxiconazole in 2000 and 2001 (based on 612 isolates). The figure shows the number of isolates which were controlled at a specific dose. For flusilazole, there was an indication of a bimodal distribution with peaks at 0.041 and 10 mg/l, whilst for epoxiconazole, the distribution was unimodal with a peak between 3.33 and 10 mg/l. Flusilazole is inherently less active against Rhynchosporium than is epoxiconazole and was available to barley growers several seasons before epoxiconazole was approved. It was therefore not surprising that isolates tended to be less sensitive to flusilazole than to epoxiconazole in 2000. The 2001 and 2002 sensitivity data for epoxiconazole described earlier indicate that a bimodal sensitivity distribution is now established for both flusilazole and epoxiconazole and that the pattern is similar to that described for triadimenol by Kendall *et al*. (1993).

Figure 3.3 Comparison of the sensitivity of Rhynchosporium to flusilazole and epoxiconazole in 2000 and 2001



Differences in sensitivity following fungicide treatment

In 2000, Rhynchosporium isolates were obtained from untreated plots and those which had received a single treatment of epoxiconazole (Opus). The sensitivity of the isolates was tested against epoxiconazole and flusilazole. Following a single application of the triazole fungicide, the epoxiconazole and flusilazole sensitivity of isolates from epoxiconazole-treated plots was greater than the sensitivity of isolates from the untreated plots i.e. mean MIC values lower (Table 3.3). This result has been reported by other researchers (Burnett & Zziwa 1997) where a single treatment can narrow the range of sensitivities.

Table 3.3 Spring barley trials 2000 (Log dose trial (Spring barley) 0003, 0004)

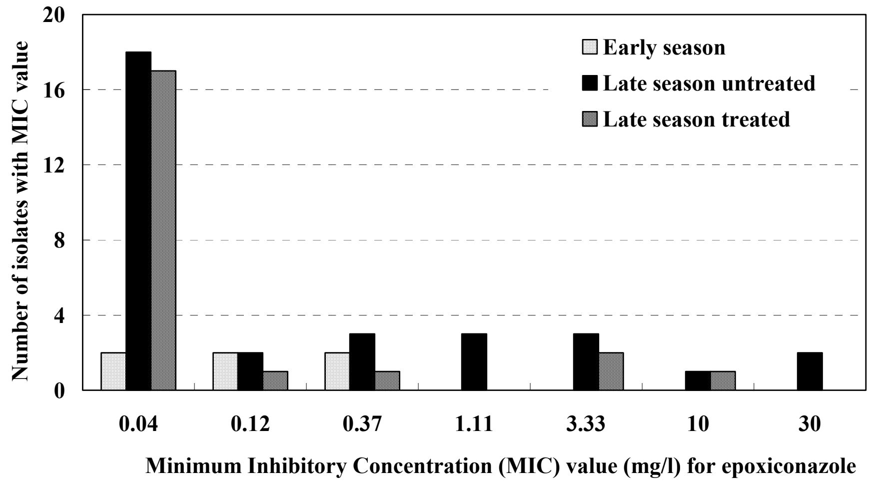
Treatment	Site	Mean MIC value (mg/l)	
		epoxiconazole	flusilazole
No fungicide	Blairnathort Fife 0003	6.162	9.86
	Orwell Fife 0004	12.339	17.20
	mean	**9.251**	**13.53**
Opus once (Tr. 7)	Blairnathort Fife 0003	2.128	7.75
	Orwell Fife 0004	7.987	12.06
	mean	**5.058**	**9.90**
No of isolates tested		106	117
SED site		2.586	4.924
SED fungicide		2.586	4.924
Wald statistic Site		9.20	0.19
Wald statistic fungicide		5.26	1.08
Significance Site		0.002	Ns
Significance Fungicide		0.022	Ns

In 2001 there appeared to be no effect on sensitivity following a single treatment. (Table 3.4 & Figure 3.4)

Table 3.4 Winter barley 2001, number of isolates in specific MIC dose categories for epoxiconazole sensitivity following no fungicide or a single treatment

Treatment	Number of isolates in each category						
	Dose categories (MIC mg/l)						
	0.041	**0.123**	**0.37**	**1.11**	**3.33**	**10**	**30**
Early season untreated	2	2	2	0	0	0	0
Late season untreated	18	2	3	3	3	1	2
Late season treatment applied Tr. 7 Opus	17	1	1	0	2	1	0

Figure 3.4 Winter barley 2001, effect of fungicide treatment on sensitivity of Rhynchosporium to epoxiconazole



In 2002, Rhynchosporium isolates were taken from three sensitivity field trial sites (East Scotland, West Scotland and Northern Ireland). The results (Table 3.5) show that there was a significant difference in the sensitivity of the Rhynchosporium to epoxiconazole following two treatments of Opus. The average minimum inhibitory concentration of isolates from untreated plots was 1.9 mg/l and from the epoxiconazole-treated plots was 3.9 mg/l. The bimodal pattern showed peaks at 0.041 and 3.33 mg/l for untreated crops and at 0.041 and between 1.11 and 10 mg/l for crops treated twice with epoxiconazole. Differences in sensitivities between the different sites were not significant.

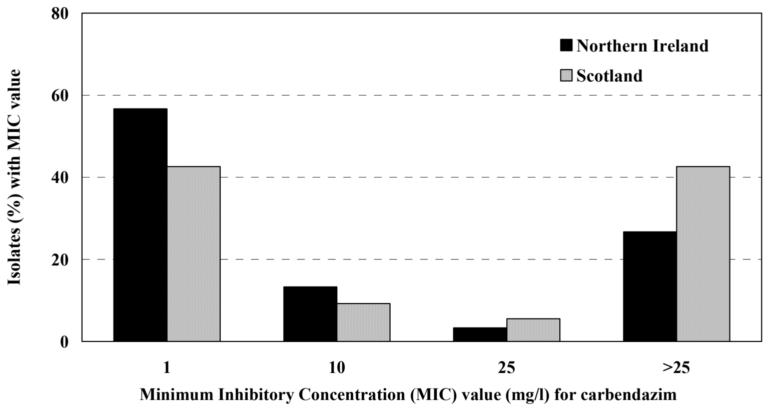
Table 3.5 Spring barley 2002, number of isolates in specific MIC dose categories for epoxiconazole sensitivity following no fungicide or a single treatment

Treatment	Number of isolates in each category						
	Dose categories (MIC mg/l)						
	0.041	0.123	0.37	1.11	3.33	10	30
Late season untreated	20	1	8	6	10	5	0
Late season treatment applied	8	1	0	11	6	11	0

Sensitivity to carbendazim

Carbendazim is no longer approved for use alone to control Rhynchosporium, but it is co-formulated with flusilazole in Punch C. Rhynchosporium isolates taken from four trials in 2000 were tested for their sensitivity to carbendazim. Results in Figure 3.5 (based on 84 isolates) show that there is a marked bimodal pattern with peaks at <1 or >25 mg/l; isolates being either sensitive or resistant to carbendazim. At all sites tested (three in Scotland and one in Northern Ireland), a substantial proportion of isolates tested were resistant to carbendazim. It is possible therefore that Rhynchosporium isolates may be resistant to both active ingredients present in Punch C.

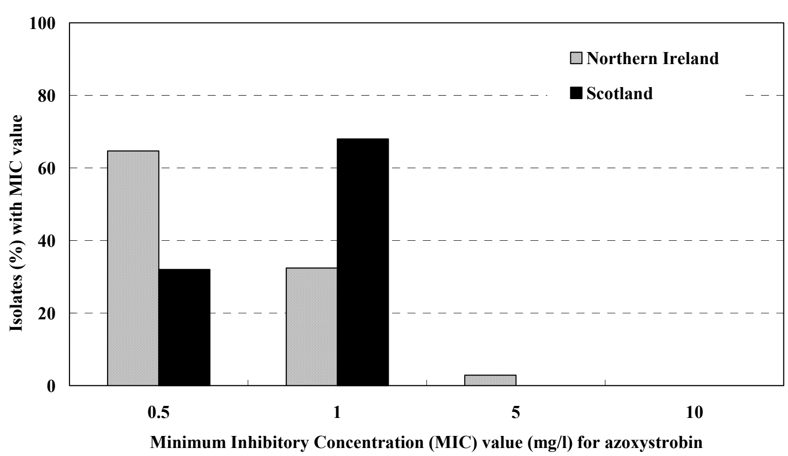
Figure 3.5 Sensitivity of Rhynchosporium to carbendazim in 2000



Sensitivity to azoxystrobin

Resistance to strobilurin fungicides (QoI's) is common in wheat and barley powdery mildew and has recently been discovered in *Septoria tritici* in wheat using PCR techniques which can detect the single gene change which confers resistance. The Rhynchosporium testing for sensitivity to azoxystrobin used a bioassay technique (developed by Syngenta), which should reflect the sensitivity occurring in the field. Limited testing from two sites in 2000 (34 isolates from Northern Ireland and 25 isolates from Scotland) indicated that Rhynchosporium isolated from five spring barley varieties was sensitive to azoxystrobin (Figure 3.6). More intensive monitoring will be required for this group of fungicides in the future, particularly since they currently play an important part in controlling Rhynchosporium.

Figure 3.6 Sensitivity of Rhynchosporium to azoxystrobin



Sensitivity to cyprodinil

Table 3.6 and Figure 3.7 show the sensitivity to cyprodinil of isolates from one trial in 2001 following treatment. The results show a unimodal pattern of sensitivity with the single peak at 1 mg/l. Figure 3.8. summarises the cyprodinil sensitivity of 538 isolates from eight trials in 2000 and 2001. There was little difference in overall sensitivity between 124 isolates from cyprodinil-treated and 414 isolates from non-cyprodinil-treated plots, however, the only two isolates with MIC values of 10 mg/l were obtained from cyprodinil-treated plots.

Table 3.6 Winter barley 2001, number of isolates in specific MIC dose categories for cyprodinil sensitivity following no fungicide or a single treatment

Treatment	Number of isolates in each category				
	Dose categories (MIC mg/l)				
	0.001	**0.01**	**0.1**	**1**	**10**
Early season untreated	0	0	2	4	0
Late season untreated	1	1	9	21	0
Late season treatment applied	0	0	6	25	1

Figure 3.7 Sensitivity to cyprodinil of Rhynchosporium from winter barley 2001

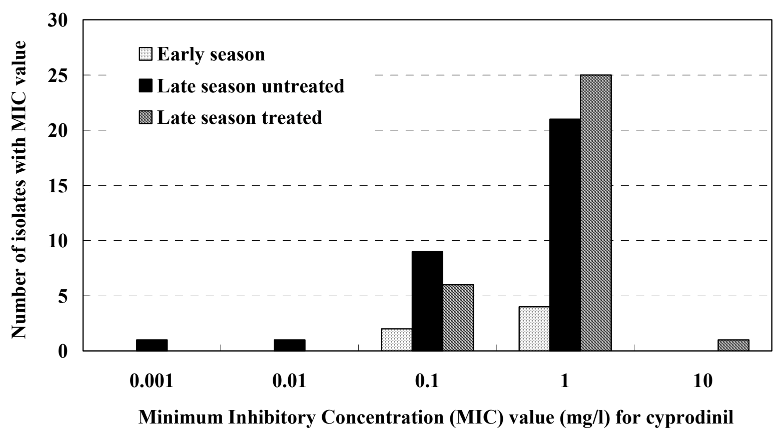
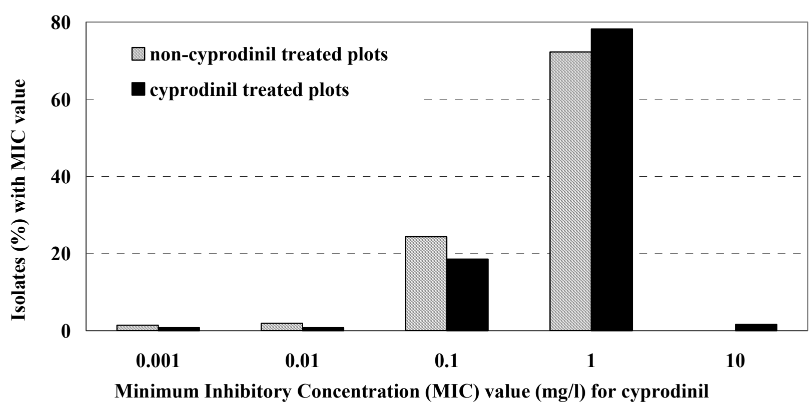


Figure 3.8 Sensitivity to cyprodinil of Rhynchosporium from eight trials in 2000-2001



Varietal differences in fungicide sensitivity

Spring barley varieties

Rhynchosporium was isolated from untreated plots of each variety from the trials detailed in Section 2. Isolates were tested for sensitivity to epoxiconazole, flusilazole and cyprodinil. Differences in sensitivity to epoxiconazole were seen between different sites in the same year and also between years. There was a tendency for the Rhynchosporium isolated from the variety Pewter to be more sensitive to epoxiconazole (i.e. easier to control) than that from other varieties, in particular Riviera. This observation was seen at three sites (Table 3.7 and Figure 3.9). This pattern was repeated for the triazole fungicide flusilazole when comparing Pewter with Riviera (Table 3.8 and Figure 3.10). There were no significant effects of either site or variety on sensitivity to cyprodinil (Table 3.9 and Figure 3.11).

Table 3.7 Sensitivity to epoxiconazole as influenced by spring barley variety

Site and year/	Mean MIC value (mg epoxiconazole/l)						SED
no. of isolates	Century	Chariot	Landlord	Optic	Pewter	Riviera	variety
N Ireland 2000	1.932	*	3.816	3.843	0.123	2.715	2.137
No. of isolates	6	0	11	15	1	6	
Perthshire 2000	*	2.919	2.537	2.825	*	1.526	
No. of isolates	0	20	23	21	0	15	
Annan Dumfries 2001	*	*	0.1114	*	0.0410	*	0.8880
No. of isolates	0	0	7	0	10	0	
Perthshire 2001	0.0410	0.1271	0.3206	0.1369	0.0985	2.0852	
No. of isolates	1	21	5	18	10	19	

	2000	2001
Wald statistic Site	0.35	1.52
Significance Site	Ns	Ns
Wald statistic variety	2.07	18.10
Significance variety	Ns	0.003

Figure 3.9 Comparison of the sensitivity of isolates to epoxiconazole taken from Riviera and Pewter in 2001

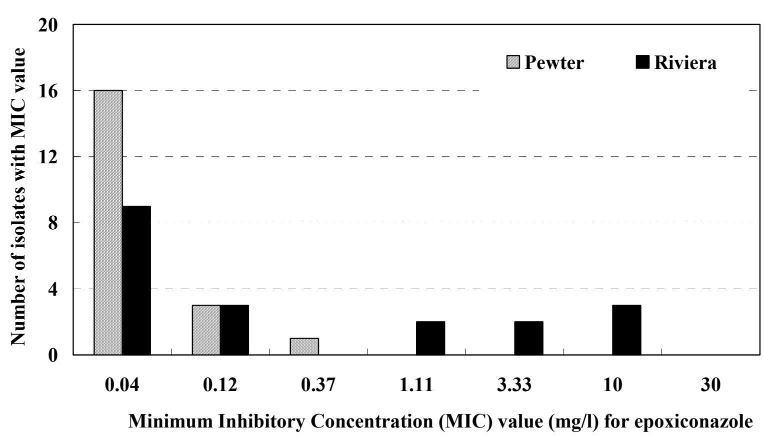


Table 3.8 Sensitivity to flusilazole as influenced by spring barley variety

Site and year	Mean MIC value (mg flusilazole/l)						SED
	Century	Chariot	Landlord	Optic	Pewter	Riviera	variety
N Ireland 2000	3.353	*	4.236	12.009	0.041	5.956	
No. of isolates	4	0	11	10	1	5	6.165
Perthshire 2000		4.457	2.311	0.589		1.806	
No. of isolates	0	3	6	6	0	6	
Annan Dumfries 2001	*	*	0.1584	*	0.0656	*	
No. of isolates	0	0	7	0	10	0	2.394
Perthshire 2001	0.0410	0.2446	0.1066	1.3804	0.3370	5.2431	
No. of isolates	1	21	5	18	10	19	

* indicate no data available

	2000	2001
Wald statistic Site	1.97	1.86
Significance Site	Ns	Ns
Wald statistic variety	2.31	14.79
Significance variety	Ns	0.011

Figure 3.10 Comparison of the sensitivity of isolates to flusilazole taken from Riviera and Pewter in 2001

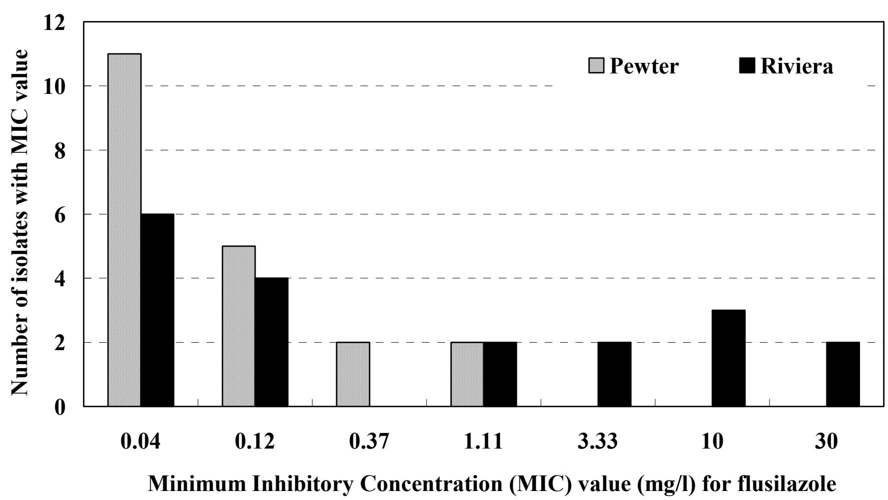


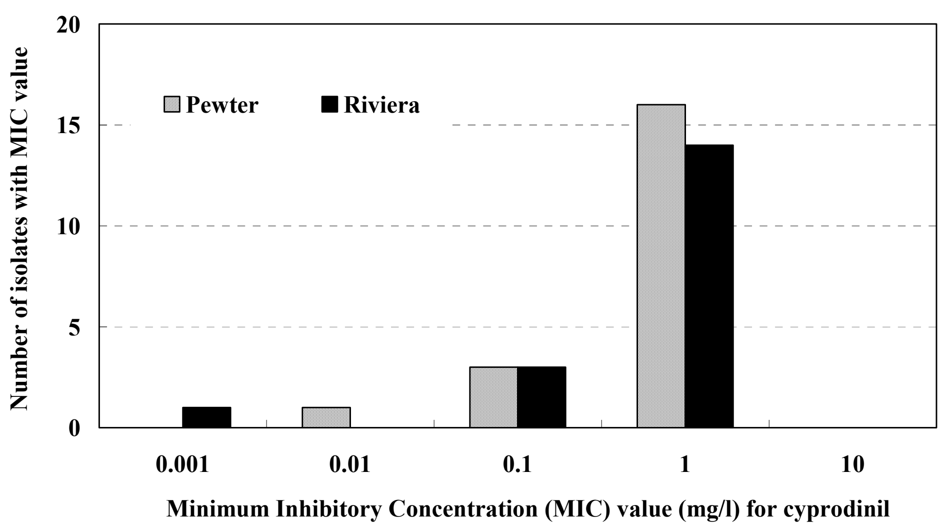
Table 3.9 Sensitivity to cyprodinil as influenced by spring barley variety

Site and year	Mean MIC value (mg cyprodinil/l)						SED
	Century	Chariot	Landlord	Optic	Pewter	Riviera	variety
N Ireland 2000 No. of isolates	1.000 1	0.828 18	0.615 22	0.969 16	0.460 5	0.887 14	1.801
Perthshire 2000 No. of isolates	1.000 8	0.659 6	0.775 4	0.438 5	1.000 2	3.857 6	
Annan Dumfries 2001 No. of isolates	* 0	* 0	0.7000 6	* 0	0.7300 10	* 0	0.2050
Perthshire 2001 No. of isolates	1.0000 1	0.7632 19	0.8200 5	0.8500 18	0.9010 10	0.7945 18	

*indicate no data available

	2000	2001
Wald statistic Site	0.65	0.88
Significance Site	Ns	Ns
Wald statistic variety	0.83	1.23
Significance variety	Ns	Ns

Figure 3.11 Comparison of the sensitivity of isolates to cyprodinil taken from Riviera and Pewter in 2001



Winter barley varieties

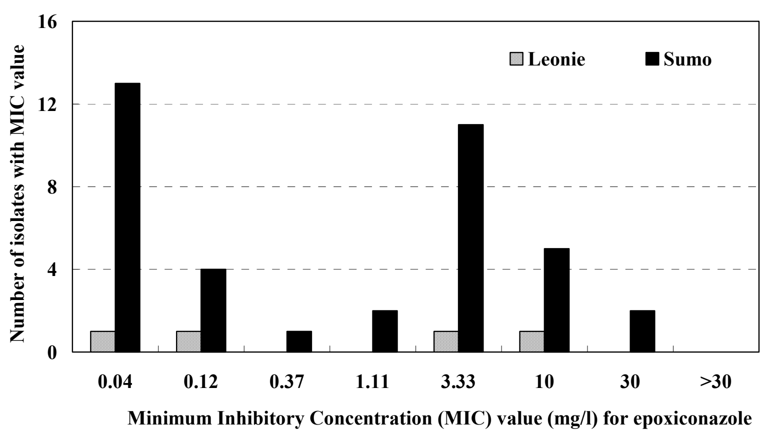
Differences in sensitivity to epoxiconazole were noticeable in 2001, but not in 2002. Differences between resistant and susceptible varieties (e.g. Leonie and Sumo) are not as marked as they were in spring barley varieties. (Table 3.10). Note that the sensitivity is showing a bimodal pattern in 2001 (Figure 3.12) with peaks at 0.041 and 3.3 mg/l.

Table 3.10 Sensitivity to epoxiconazole as influenced by winter barley variety

Site and year	Mean MIC value (mg epoxiconazole/l)						SED
	Intro	Jackpot	Leonie	Pastoral	Sumo	Siberia	variety
Perthshire 2001	1.016	6.606	*	0.937	1.622	3.552	3.062
No. of isolates	17	24	0	31	15	31	
Midlothian 2001	14.922	8.377	3.374	4.357	5.524	5.973	
No. of isolates	15	23	4	26	23	42	
Annan 2002	3.941	4.089	*	3.514	4.207	3.148	0.4546
No. of isolates	17	21	0	29	21	19	
Midlothian 2002	3.996	3.810	*	3.038	3.380	3.211	
No. of isolates	28	21	0	24	36	41	

	2001	2002
Wald statistic Site	11.28	2.5
Significance Site	<0.001	Ns
Wald statistic variety	11.81	10.57
Significance variety	0.04	0.03

Figure 3.12 Comparison of the sensitivity of isolates to epoxiconazole taken from Leonie and Sumo in 2001



In 2001, there were significant differences in the sensitivity of flusilazole between the sites, but not between the varieties (Table 3.11) and Figure 3.13). The sensitivity to flusilazole shows a bimodal pattern with peaks at 0.041 and 10 mg/l.

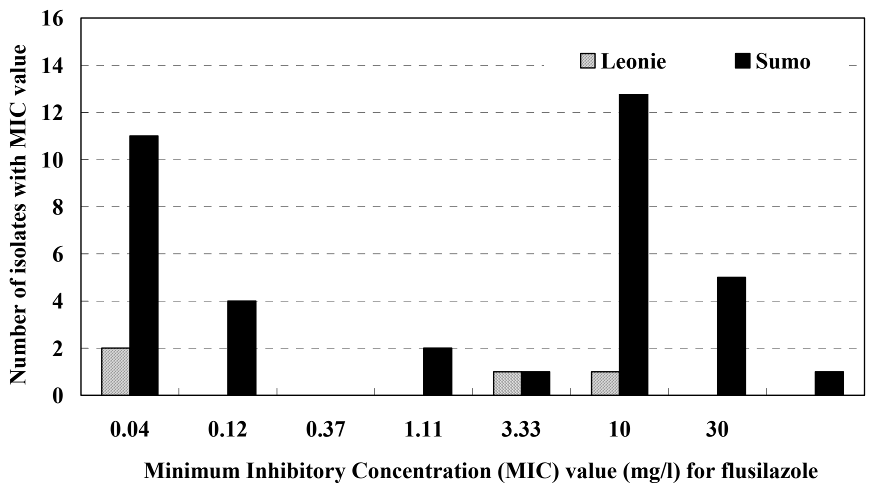
Table 3.11 Sensitivity to flusilazole as influenced by winter barley variety

Site and year	Mean MIC value (mg flusilazole/l)						SED
	Intro	Jackpot	Leonie	Pastoral	Sumo	Siberia	variety
Perthshire 2001	3.381	9.165	*	3.515	7.226	4.784	3.456
Midlothian 2001	13.602	10.199	3.353	7.047	9.375	7.954	
No. of isolates							

*indicate no data available

	2001
Wald statistic Site	6.82
Significance Site	0.009
Wald statistic variety	7.15
Significance variety	Ns

Figure 3.13 Comparison of the sensitivity of isolates to flusilazole taken from Leonie and Sumo in 2001



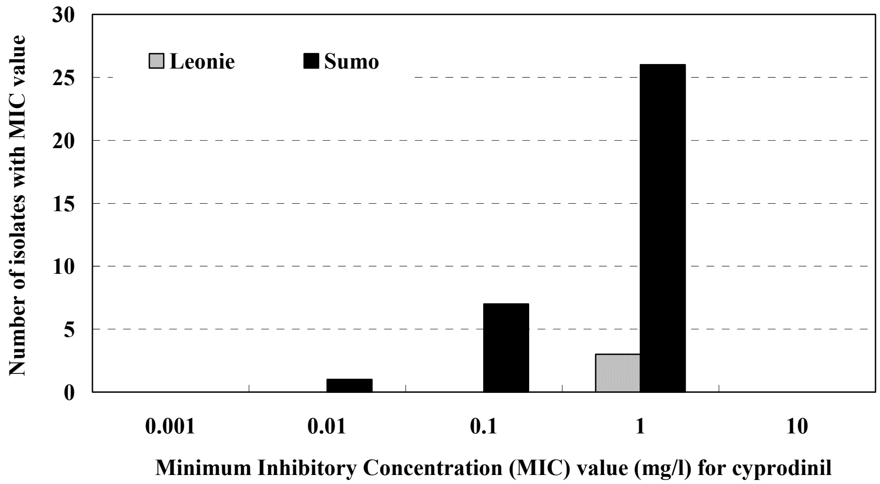
In 2001, there were no significant differences between sites or varieties in the sensitivity of cyprodinil (Table 3.12 and Figure 3.14). The sensitivity distribution was unimodal.

Table 3.12 Sensitivity to cyprodinil as influenced by winter barley variety

Site and year	Mean MIC value (cyprodinil/l)						SED
	Intro	Jackpot	Leonie	Pastoral	Sumo	Siberia	variety
Perthshire 2001	0.7446	0.6416	*	0.5914	0.7682	0.8388	0.1605
Midlothian 2001	0.7318	0.7579	1.0000	0.6760	0.7578	0.7509	
No. of isolates							

	2001
Wald statistic Site	0.01
Significance Site	Ns
Wald statistic variety	4.23
Significance variety	Ns

Figure 3.14 Comparison of the sensitivity of isolates to cyprodinil taken from Leonie and Sumo in 2001



Discussion

Differences between fungicides.

The results show that the sensitivity of Rhynchosporium to the triazole fungicide epoxiconazole has declined from 1998 to 2002 in Scotland and Northern Ireland. There are also significant differences in the sensitivity of Rhynchosporium isolates at different sites within a season to the triazole fungicides epoxiconazole and flusilazole, particularly in 2001. The results confirm observations by Cooke & Locke (2002) that triazole sensitivity of Rhynchosporium isolates was lower after treatment with a triazole fungicide treatment than before. Kendall *et al*. (1993) observed a decline in sensitivity to propiconazole and triadimenol, which, in the case of triadimenol, involved a shift from a unimodal to a bimodal sensitivity distribution. Results from the present study showed that epoxiconazole sensitivity had a unimodal distribution with a long tail in 2000 and 2001, which became bimodal in Scotland in 2002, while flusilazole sensitivity had a bimodal distribution in both years in which isolates were tested. There is an indication than Rhynchosporium is currently more sensitive to epoxiconazole in Northern Ireland than in Scotland. It can be concluded that the sensitivity of the Rhynchosporium population to DMI fungicides is continuing to shift in the direction of increasing resistance. The results also affirm the fact that applying a triazole fungicide alone more than once to a crop will increase the proportion of Rhynchosporium resistant to that fungicide.

No significant differences were detected in the sensitivity of Rhynchosporium to cyprodinil (Unix) between or within sites, which suggests cyprodinil may currently give a more consistent performance than epoxiconazole or flusilazole. No sensitivity shift was detected to the QoI fungicide azoxystrobin, but in the light of the recent development of QoI resistance in *Septoria tritici*, this situation should continue to be monitored. Data for carbendazim showed that this fungicide will no longer provide effective control when used alone and, since this fungicide is co-formulated with flusilazole in Punch C, suggests that the co-formulation may also achieve unpredictable control.

Differences between varieties

The most interesting observations relate to an apparent association between varietal resistance and DMI sensitivity, with the more resistant varieties tending to yield the more sensitive isolates. This is most marked in the spring variety Pewter, which yielded isolates more sensitive to epoxiconazole than did the more susceptible variety Riviera. However, this observation needs to be interpreted in the light of the much lower numbers of isolates which were recovered from Pewter compared with more susceptible varieties; since resistant isolates are relatively infrequent within the Rhynchosporium population (although having a large effect on mean sensitivity), the chances of obtaining them from Pewter are much lower than from Riviera.

In the winter barley, there was some indication that the resistant variety Leonie tended to yield isolates with a greater mean sensitivity than did the susceptible varieties, but again this may be related to the very low numbers of isolates recovered from this variety.

The lack of isolates from the most resistant spring and winter barley varieties reflects the low incidence of Rhynchosporium on their plots and the poor viability of the limited infection which was present. This provides further evidence for the effectiveness of varietal resistance in combating Rhynchosporium. The effect was particularly marked for Leonie: in 2001 a total of only four isolates was obtained from this variety in the two trials, whereas the other five varieties each yielded a mean of 25 isolates/trial, and in 2002 no viable isolates were obtained from Leonie, compared with a mean of 26 isolates/trial for all other varieties. This merits further investigation, since Leonie, with a resistance rating of 9, performed markedly more effectively in reducing viable Rhynchosporium than did the next most resistant variety Jackpot (rating 8).

The apparent association between higher varietal resistance and greater sensitivity of Rhynchosporium to DMIs may be related to the distribution of sensitivity within the

Rhynchosporium population as discussed above or it might indicate that Rhynchosporium isolates which are less sensitive to epoxiconazole are less virulent on more resistant varieties such as Pewter and Leonie. This observation could be investigated by inoculating Rhynchosporium isolates sensitive and less sensitive to epoxiconazole onto Pewter and onto more susceptible varieties, to see if a link between fungicide resistance and virulence could be demonstrated in spring barley. If a link were confirmed, this information could be used in breeding new varieties, whose resistance would be less easily eroded if they were protected by triazole fungicides and which would also help to provide an anti-resistance strategy against further loss of sensitivity to DMIs.

4 General Discussion

Introduction

Rhynchosporium secalis remains one of the most common diseases in both winter and spring barley and this study attempts to understand effective methods of disease control based on:

1) Knowledge of varietal resistance both early and late in the season
2) Development of the disease through a season
3) Effectiveness of fungicides at different doses when applied alone
4) Effect of fungicide timing on control and yield
5) Effectiveness of fungicide mixtures, including beneficial and detrimental effects of mixtures on disease control, yields, specific weight and green leaf
6) The impact of differences in the sensitivity of fungicides to Rhynchosporium.

During the study other interactions were found between varietal resistance and triazole sensitivity. Such interactions may be of greater interest to growers in the future if fewer new fungicides are developed and resistance develops to existing fungicides.

Knowledge of varietal resistance both early and late in the season

Current CEL resistance ratings for Rhynchosporium on spring barley varieties are in general agreement with the results of the project. Rhynchosporium resistance ratings for winter barley varieties proved more problematic. For example, Sumo has a resistance rating of 5, but to bring it in line with the ratings of spring barley varieties with similar disease levels (e.g. Optic), it should have a lower rating (3).

The majority of winter barley varieties have Rhynchosporium resistance ratings of 7 or 8 which would be perceived by growers to be relatively resistant. If susceptible varieties were to be 'downgraded' this would result in winter varieties with ratings of 7 or 8 being down graded to ratings of 5-7. This downgrading would help growers since a variety with a rating of 8 could be thought to have good resistance, but if such varieties were downgraded to 6, growers may expect the variety to be affected in high risk areas.

The reason why resistance ratings may be inaccurate in winter barley is due to the time of assessments. Most assessments are carried out late in the season on the upper leaves. Rhynchosporium however attacks the winter crop in the autumn and the disease reaches a peak on the lower leaves at boot stage GS45. Disease then develops on the upper leaves, reaching a peak at milk development (GS70+). This second peak of disease is usually lower than the first and for some varieties, the early disease peak is very much higher. When assessments are made late in the season, disease which may have been present on the lower leaves is likely to have killed them, hence the leaves most affected will not be assessed.

Any difference in the susceptibility of a variety to early Rhynchosporium as opposed to late infection is likely only to be determined through detailed leaf assessments throughout the season which is likely to be cost prohibitive in Recommended List variety trials.

Spring barley ratings are more realistic and this may reflect the fact that the Recommended List assessments are carried out late in the season when the highest disease levels occur.

Disease development

It is common for Rhynchosporium to be present on winter barley early in the spring with disease peaks in April and May. In recent years, there has also been a second peak of disease in June or July. Spring barley crops also have two peaks of disease. They generally show little disease in March and April and the first peak of diseases develops in May (following on from the first disease peak on the winter crop). The second peak occurs in July (following on from the second disease peak on the winter crop). Sowing of the winter crop in August means there is a green bridge effect throughout the season for Rhynchosporium

Effectiveness of fungicides at different doses when applied alone

Seasonal patterns of Rhynchosporium are helpful to the grower in knowing when the disease is likely to reach a peak. It should be emphasised however that fungicide applications must be applied well in advance of the peak in disease. Treating crops when disease levels are at their highest will achieve poor results since fungicides are ineffective at eradicating Rhynchosporium.

This study shows that controlling Rhynchosporium with a single fungicide will give poor results. This includes new fungicides (e.g. the DMI fungicide HGCA3 and strobilurin fungicides (QoIs)). Eradicating Rhynchosporium is very difficult, but many fungicides can help protect against Rhynchosporium. This explains why Rhynchosporium is potentially easier to manage in spring barley compared to winter barley since there is an opportunity to protect the spring crop before symptoms appear, whilst the winter crop commonly has disease present before any fungicide has been applied. Growers who are reluctant to treat Rhynchosporium in the spring crop until symptoms are seen are likely to struggle to control it. Advice to spend money on fungicides on a spring crop, which has no visible disease, may be ignored by some growers, but in high disease pressure areas may be more cost effective than waiting until the disease appears before taking action.

Effect of fungicide timing on control and yield

Trials on both winter and spring barley indicated that the early treatments achieved the best disease control of the early epidemic and the best yields in the winter crop. Later treatments were however required for the later epidemic in Rhynchosporium and in recent years also result in the best yields in the spring crop. The later treatment is important to maintain green leaf area otherwise lost from Ramularia and abiotic leaf spots. (In areas where brown rust is a common problem, the later treatment will be important to control this disease). Attempting a single treatment between the two Rhynchosporium epidemics tended to result in poor disease control, loss of yield and quality as well as incurring the expense of applying a fungicide.

Where the market is for high quality grain (as in malting barley), fungicides are important to achieve effective control of Rhynchosporium, which in turn provides the highest yield and quality. If the final product is for feed and quality is of no importance, there may be more scope to take risks with disease control. If risks are to be taken, it should be understood that should the disease levels become high, there are no effective methods to eradicate Rhynchosporium.

Effectiveness of individual fungicides used in a mixture

Morpholine fungicides (e.g. Corbel) have a limited eradicant effect on Rhynchosporium. This property makes them a useful component of a mixture if the crop has Rhynchosporium present. The same fungicide also had a negative effect on yield if it is applied late to a crop, in particular spring barley. This side effect can be avoided by ensuring disease is well controlled early so no disease eradication is required late in the season.

Cyprodinil (Unix) has a better effect on the yield of the winter crop than on the spring crop. This can be explained by the fact the fungicide will also control other diseases including eyespot, which are likely to affect the winter crop. There was no evidence of reduced sensitivity to cyprodinil in Rhynchosporium isolates tested in this study and there were no sensitivity differences from site to site. This suggests that although the level of control from using this product alone is average, it currently makes a stable mixing partner. Research on late use of cyprodinil shows it gives poor control of barley leaf spots. It is also incompatible with some plant growth regulators (e.g. Terpal or Cerone). These factors overall make it more useful as an early fungicide in barley, particularly in winter barley.

The triazole fungicide epoxiconazole (Opus) can give control of Rhynchosporium when used in a mixture as previously reported (Cooke & Locke, 2002), but the shift in the sensitivity of Rhynchosporium to this fungicide is continuing. Resistance to triazole fungicides is not qualitative, but it is evident that in sites in 2000 – 2002 a normal distribution of isolates for sensitivity no longer exists. In 2001 and 2002 some isolates were unlikely to be effectively controlled in the field if epoxiconazole had been applied alone. It was also evident that the Rhynchosporium isolates were less sensitive to epoxiconazole later in the season where this fungicide had been applied.

In 2001, there was variation between sites in the sensitivity of their Rhynchosporium to epoxiconazole. At the start of this study it was assumed that the most resistant Rhynchosporium isolates were likely to occur at intensive barley sites, but this study shows that it is not possible to forecast the sites where isolates less sensitive to epoxiconazole exist.

Epoxiconazole may no longer be consistent in controlling Rhynchosporium and its use should be limited in a programme to reduce the selection of resistant isolates as previously recommended (Cooke & Oxley, 2001; Cooke & Locke, 2002). Other trials showed it has useful properties in controlling Ramularia and maintaining green leaf area where used late in the season. The fungicide also showed a trend towards improving the specific weight when used in mixtures.

Epoxiconazole may no longer be consistent in controlling Rhynchosporium and its use should be limited in a programme to reduce the selection of insensitive isolates. Other trials showed it has useful properties in controlling Ramularia and maintaining green leaf area where used late in the season. The fungicide also showed a trend towards improving the specific weight when used in mixtures.

Rhynchosporium isolates were less sensitive to flusilazole than they were to epoxiconazole in line with its lower inherent activity. The product Punch C includes flusilazole and carbendazim. It was clear that isolates resistant to carbendazim were common in the sites tested. Punch C does not have the same positive properties in maintaining green leaf area or controlling leaf spots as epoxiconazole. Overall this means Punch C may no longer be a consistent fungicide to control Rhynchosporium.

Chlorothalonil had a beneficial effect on the yield, but this may be a result of maintaining green leaf area and minimising barley leaf spots rather than in its control of Rhynchosporium. This fungicide does show good protectant activity against Rhynchosporium, but no eradicant activity.

The new DMI (triazole) HGCA3 was the most effective at controlling Rhynchosporium and also achieved the best yield response. When HGCA3 is present on the market, there is no doubt it will be an excellent fungicide for barley, but can lessons be learnt on the best ways to use it? Growers might be tempted to use this fungicide throughout the programme without regard for any potential shift in sensitivity of the pathogen (and regardless of recommendations for its use). If manufacturers had a range of new and different fungicides coming along, this strategy might work for a limited time. The current situation is however different. There are currently no obvious new active ingredients likely to be introduced in the next few years. Sensitivity of the Rhynchosporium population is continuing to decline to the current DMIs flusilazole and epoxiconazole just as it did to the earlier triazoles triadimenol and propiconazole. HGCA3 is a DMI with the same mode of action so over-use of this fungicide is likely to result in a continuing erosion of sensitivity. It is therefore important that when using HGCA3 growers follow previously published guidelines aimed at reducing selection of DMI-resistant Rhynchosporium (Cooke & Oxley, 2001).

Strobilurin fungicides achieved reasonable control of Rhynchosporium when used in mixtures and 2002 data suggest that they have a major contribution to Rhynchosporium control. In the 2002 season trials, their impact on maintaining green leaf area and barley leaf spots late in the season was less obvious, but they did have a positive effect on yield over other components of the mixture.

Sensitivity data from this study shows that Rhynchosporium strains resistant to the strobilurin fungicide azoxystrobin were not detected in 2000, but the recent occurrence of resistance of strobilurin fungicides in *Septoria tritici* would suggest that we cannot assume strobilurin fungicides will continue effective in the longer term. Further studies should monitor strobilurin sensitivity in both Rhynchosporium and Ramularia, but it is also important that future mixture research looks at non-strobilurin mixtures which could be used should resistance occur.

Managing fungicide resistance through variety choice is an interesting concept and one which has previously been exploited in the management of lettuce downy mildew. Results from isolates taken from spring barley varieties suggest that the Rhynchosporium present on resistant varieties (i.e. Pewter) may be more sensitive to epoxiconazole. If the future supply of fungicides is to be limited, such interactions are worth investigating in plant breeding programmes.

5 Appendix 1

Summary of field trials in study

Study number	Spring /winter	Site	County	Region	Trial type	Harvest year
00487(0001)	Spring	Annan Dumfriesshire	Dumfries	West	Variety x timing	2000
00487(0002)	Spring	Tibbermore (Perthshire)	Perthshire	East	Variety x timing	2000
00487(0003)	Spring	Blairnathort (Fife)	Fife	East	Log dose	2000
00487(0004)	Spring	Orwell (Fife)	Fife	East	Log dose	2000
SBQUB00	Spring	Belfast	Belfast	N Ireland	Variety x Timing	2000
00487(0101)	Winter	Tibbermore Perthshire	Perthshire	East	Variety x timing	2001
00487(0102)	Winter	Bush Midlothian	Midlothian	East	Variety x timing	2001
00487(0103)	Winter	Kirkton Dunfermline	Fife	East	Log dose	2001
00487(0104)	Winter	Balado Kinross	Fife	East	Log dose	2001
00487(0105)	Spring	Annan Dumfrieshire	Dumfries	West	Variety x timing	2001
00487(0106)	Spring	Tibbermore Perthshire	Perthshire	East	Variety x timing	2001
00487(0107)	Spring	Bush Midlothian	Midlothian	East	Mixture development	2001
SBQUB01	Spring	Belfast	Belfast	N Ireland	Variety x timing	2001
00487(0201)	Winter	Bush Midlothian	Midlothian	East	Variety x timing	2002
00487(0202)	Winter	Anna Dumfrieshire	Dumfries	West	Variety x timing	2002
00487(0203) WBQUB02	Winter	Belfast	Belfast	N Ireland	Variety x timing	2002
00487(0204)	Winter	Balmonth Fife	Fife	East	Mixture development	2002
00487(0205)	Winter	Dunecht Aberdeenshir e	Aberdeen shire	North	Mixture development	2002
00487(0206)	Spring	Balmonth Fife	Fife	East	Mixture development	2002
00487(0207)	Spring	Islabank Perthshire	Perthshire	East	Mixture development	2002
00487(0208)	Spring	Bush Midlothian	Midlothian	East	Sensitivity testing	2002
00487(0209) SBQUB02	Spring	Belfast	Belfast	N Ireland	Sensitivity testing	2002
00487(0210)	Spring	Annan Dumfrieshire	Dumfries	West	Sensitivity testing	2002

Barley mixture trial data

Results from barley mixture trials in 2001

Table Fungicide mixtures tested in 2001 on spring barley

	GS25-30 and GS39-45	Mix
1	Nil	
2	Unix 0.5 kg/ha	U
3	Opus 0.45 l/ha	T
4	Punch c 0.4 l/ha	TM
5	Amistar 0.5 l/ha	S
6	Twist 1.0 l/ha	S
7	Unix 0.5 + Corbel 0.4	UC
8	Opus 0.5 + Corbel 0.4	TC
9	Punch C 0.4 + Corbel 0.4	TMC
10	Amistar 0.5 + Corbel 0.4	SC
11	Twist 1.0 + Corbel 0.4	SC
12	Unix 0.5 + Mycoguard 1.0	UB
13	Opus 0.5 + Mycoguard 1.0	TB
14	Punch c 0.4 + Mycoguard 1.0	TMB
15	Amistar 0.5 + Mycoguard 1.0	SB
16	Twist 1.0 + Mycoguard 1.0	SB
17	Unix 0.5 + Opus 0.5	UT
18	Unix 0.5 + Punch c 0.4	UTM
19	Unix 0.5 + Twist 1.0	US
20	Unix 0.5 + Amistar 0.5	US

Mix: T=triazole, U=Unix, S=strobilurin, C=Corbel, B=Chlorothalonil, M=MBC

% Rhynchosporium 2001 Spring barley

Treatment	GS32-45	GS49-69 bottom leaves	GS49-69 top leaves	GS70-80 bottom	GS70-80 top	T/ha
Nil	0.5	0.3	1.3	13.0	20.8	5.933
Unix 0.5 kg/ha	0	0.3	0.5	2.5	11	6.081
Opus 0.45 l/ha	0.1	0.3	0.3	3.3	3.8	6.32
Punch c 0.4 l/ha	0	0.3	0.5	0.3	3.8	6.278
Amistar 0.5 l/ha	0.5	0.5	1.3	3	5	6.287
Twist 1.0 l/ha	0	0	0.3	0.3	2	6.278
Unix 0.5 + Corbel 0.4	0	0	0	0	2.8	6.27
Opus 0.5 + Corbel 0.4	0	0	0	0	0.3	6.306
Punch C 0.4 + Corbel 0.4	0	0	0	0	0.3	6.297
Amistar 0.5 + Corbel 0.4	0	0	0	0	0	6.307
Twist 1.0+Corbel 0.4	0	0	0	0	0	6.364
Unix 0.5 + Mycoguard 1.0	0	0	0	0	1.3	6.173
Opus 0.5 + Mycoguard 1.0	0	0	0	0.3	2	6.326
Punch c 0.4 + Mycoguard 1.0	0	0	0	0	2.8	6.272
Amistar 0.5 + Mycoguard 1.0	0	0	0	2.5	8.3	6.313
Twist 1.0+Mycoguard 1.0	0.1	0	0.3	0.5	4	6.356
Unix 0.5 + Opus 0.5	0	0	0	0	1	6.269
Unix 0.5 + Punch c 0.4	0	0	0	0	0	6.162
Twist 1.0+Unix	0	0	0	0	0	6.308
Unix 0.5 + Amistar 0.5	0	0	0	0	0	6.341
SED (treatments)	0.178	0.226	0.628	2.31	3.169	0.112
Sig	ns	n	ns	<.001	<.001	0.06

% Green leaf area (2001 mixture trial)

Treatment	GS49-69 bottom leaves	GS49-69 top leaves	GS70-80 bottom	GS70-80 top	GS81-90 top leaves	T/ha
Nil	82.2	96.5	40	47.5	25	5.933
Unix 0.5 kg/ha	97	95.8	56.2	61.2	30	6.081
Opus 0.45 l/ha	94.5	96.3	77.5	67.5	52.5	6.32
Punch c 0.4 l/ha	97	97.3	90	80	25	6.278
Amistar 0.5 l/ha	77.2	96.8	76.2	70	30	6.287
Twist 1.0 l/ha	96.5	97.5	88.8	75	30	6.278
Unix 0.5 + Corbel 0.4	78.8	95	81.2	65	33.8	6.27
Opus 0.5 + Corbel 0.4	96.2	96.3	83.8	71.2	42.5	6.306
Punch C 0.4 + Corbel 0.4	92	96.8	70	66.2	33.8	6.297
Amistar 0.5 + Corbel 0.4	96.5	97	85	73.8	35	6.307
Twist 1.0+Corbel 0.4	96.5	97.5	88.8	80	37.5	6.364
Unix 0.5 + Mycoguard 1.0	97.5	97.3	88.8	80	45	6.173
Opus 0.5 + Mycoguard 1.0	95.8	97	88.8	82.5	60	6.326
Punch c 0.4 + Mycoguard 1.0	97.2	97	80	76.2	26.2	6.272
Amistar 0.5 + Mycoguard 1.0	97.5	97.3	86.2	66.2	42.5	6.313
Twist 1.0+Mycoguard 1.0	95.5	97.3	75	76.2	42.5	6.356
Unix 0.5 + Opus 0.5	95.5	97.8	90	78.8	47.5	6.269
Unix 0.5 + Punch c 0.4	95.8	97.5	90	77.5	47.5	6.162
Twist 1.0+Unix	97	95.8	87.5	68.8	40	6.308
Unix 0.5 + Amistar 0.5	97.8	95.3	85	75	55	6.341
SED (treatments)	8.36	1.018	8.64	9.25	10.10	0.112
Sig	ns	Ns	<.001	0.09	0.02	0.06

Yields and Ramularia (2001 mixture trial)

Treatment	T/ha	Spwt kg/hl	%Ramularia GS70-80 top	%Leaf scorch GS70-80 top	%Ramularia GS81-90 top leaves
Treatment	5.933	63.05	13.5	16.3	6.3
Nil	6.081	62.13	14.8	6.3	5.0
Unix 0.5 kg/ha	6.320	62.48	10.5	9.0	7.5
Opus 0.45 l/ha	6.278	62.63	14.5	5.0	7.5
Punch C 0.4 l/ha	6.287	62.50	11.5	6.0	4.3
Amistar 0.5 l/ha	6.278	63.05	10.8	6.0	8.0
Twist 1.0 l/ha	6.270	62.58	19.0	14.0	8.8
Unix 0.5 + Corbel 0.4	6.306	62.33	11.8	13.8	6.3
Opus 0.5 + Corbel 0.4	6.297	62.65	18.3	13.3	9.3
Punch C 0.4 + Corbel 0.4	6.307	61.90	17.5	10.5	8.8
Amistar 0.5 + Corbel 0.4	6.364	62.53	15.8	13.8	12.5
Twist 1.0+Corbel 0.4	6.173	62.50	6.3	12.8	3.5
Unix 0.5 + Mycoguard 1.0	6.326	62.78	7.0	11.0	5.8
Opus 0.5 + Mycoguard 1.0	6.272	62.60	8.3	16.5	10.5
Punch c 0.4 + Mycoguard 1.0	6.313	62.33	7.5	13.8	9.5
Amistar 0.5 + Mycoguard 1.0	6.356	62.30	6.8	15.3	4.0
Twist 1.0+Mycoguard 1.0	6.269	62.68	13.3	5.0	6.8
Unix 0.5 + Opus 0.5	6.162	62.50	13.8	8.0	11.3
Unix 0.5 + Punch c 0.4	6.308	62.53	15.5	10.8	6.8
Twist 1.0+Unix	6.341	61.58	15.3	12.0	5.3
Unix 0.5 + Amistar 0.5					
SED (treatments)	0.112	0.520	3.08	5.59	3.346
Sig	0.06	ns	<.001	ns	ns

Table Fungicide mixtures tested in 2002 on 2 spring barley and 2 winter barley trials.

	T1	**T2**	**T1**	**T2**
	GS31-32	**GS45**	**Mix**	**Mix2**
1	Nil	Nil	0	0
2	Unix 0.5	Twist 1.0	U	S
3	Opus 0.5	Opus 0.5	T	T
4	UK756 0.4	UK756 0.4	T	T
5	Unix 0.5 + Cropgard 1.0	Twist 1.0 + Cropgard 1.0	UB	SB
6	Unix 0.5 + Corbel 0.5	Twist 1.0 +Corbel 0.5	UC	SC
7	Unix 0.5 + Acanto 0.5	Opus 0.5+Acanto 0.5	US	ST
8	Unix 0.5 + Amistar 0.5	Opus 0.5+Amistar 0.5	US	ST
9	Unix 0.5 + Twist 1.0	Opus 0.5+Twist 1.0	US	ST
10	Unix 0.5 Twist 1.0	Unix 0.5 Twist 1.0	US	US
11	Unix 0.5 + Opus 0.5	Opus 0.5+Twist 1.0	UT	ST
12	Unix 0.5 + UK756 0.4 l/ha	UK958 0.75 l/ha	UT	ST
13	Opus 0.5+Twist 1.0	Opus 0.5+Twist 1.0	ST	ST
14	UK756 0.4 l/ha + Twist 1.0	UK756 0.4 l/ha + Twist 1.0	ST	ST
15	UK958 0.75 l/ha	UK958 0.75 l/ha	ST	ST
16	Opera 0.75	Opera 0.75	ST	ST
17	Unix 0.5 + Opera 0.75	Opera 0.75	UTS	ST
18	Unix 0.5 + Twist 1.0 + Corbel 0.5	Opus 0.5 + Twist 1.0	USC	ST
19	Unix 0.5 + Opus 0.5 + Corbel 0.5	Opus 0.5 + Twist 1.0	UTC	ST
20	Opus 0.5 + Twist 1.0 + Corbel 0.5	Opus 0.5 + Twist 1.0	STC	ST

Mix: T=triazole, U=Unix, S=strobilurin, C=Corbel, B=Chlorothalonil,

Winter barley 2002 mixture trials % Rhynchosporium

Treatment	GS32-45	GS49-69 bottom leaves	GS49-69 top leaves	GS70-80 bottom	GS70-80 top	GS81-90 bottom leaves	GS81-90 top leaves
1	0.0	2.8	0.2	6.1	1.5	2.4	3.1
2	0.0	2.1	0.0	5.0	0.6	3.0	2.4
3	0.0	1.3	0.0	3.0	0.5	2.2	2.1
4	0.2	0.7	0.0	1.5	0.2	0.6	0.8
5	0.0	2.2	0.0	2.3	0.4	1.3	1.4
6	0.0	1.1	0.0	2.3	0.2	0.7	1.3
7	0.0	1.3	0.0	1.4	0.4	0.9	0.5
8	0.1	1.4	0.0	2.3	0.3	1.8	1.5
9	0.0	0.9	0.0	1.4	0.4	0.2	0.4
10	0.0	0.7	0.0	0.9	0.2	0.0	0.2
11	0.1	0.5	0.0	1.9	0.5	0.4	0.4
12	0.0	0.8	0.0	0.5	0.2	0.1	0.1
13	0.0	0.7	0.0	1.3	0.5	0.0	0.3
14	0.0	0.4	0.0	0.7	0.2	0.2	0.0
15	0.0	1.0	0.1	1.2	0.2	0.3	0.3
16	0.0	1.0	0.0	2.4	0.4	2.0	1.7
17	0.0	0.7	0.0	0.9	0.3	0.2	0.3
18	0.0	0.3	0.1	1.0	0.3	0.1	0.1
19	0.2	1.0	0.0	1.7	0.3	0.4	0.9
20	0.1	0.5	0.0	0.8	0.3	0.4	0.2
SED (treatments)	*	0.262	0.151	0.302	0.234	0.793	0.746
Sig	*	0.05	0.080	0.02	0.004	Ns	Ns

Spring barley % Rhynchosporium

Treatment	GS32	GS32-45	GS49-69 bottom leaves	GS49-69 top leaves	GS70-80 bottom leaves	GS70-80 top leaves	GS81-90 bottom leaves	GS81-90 top leaves
1	0	0.0	1.8	0.1	1.3	3.3	2.4	3.1
2	0	0.0	0.5	0.3	0.2	0.9	3.0	2.4
3	0	0.0	0.7	0.9	0.3	1.2	2.2	2.1
4	0	0.2	0.1	0.3	0.0	0.0	0.6	0.8
5	0	0.0	0.5	0.7	0.2	0.5	1.3	1.4
6	0	0.0	0.2	0.3	0.0	0.5	0.7	1.3
7	0	0.0	0.1	0.1	0.0	0.2	0.9	0.5
8	0	0.1	0.1	0.2	0.3	0.2	1.8	1.5
9	0	0.0	0.2	0.5	0.1	0.0	0.2	0.4
10	0	0.0	0.2	0.2	0.1	0.5	0.0	0.2
11	0	0.1	0.7	0.9	0.4	0.8	0.4	0.4
12	0	0.0	0.0	0.0	0.0	0.1	0.1	0.1
13	0	0.0	0.1	0.1	0.1	0.1	0.0	0.3
14	0	0.0	0.6	0.7	0.0	0.2	0.2	0.0
15	0	0.0	0.9	0.9	0.0	0.6	0.3	0.3
16	0	0.0	0.8	0.7	0.3	0.9	2.0	1.7
17	0	0.0	0.3	0.2	0.1	0.5	0.2	0.3
18	0	0.0	0.5	0.6	0.0	0.0	0.1	0.1
19	0	0.2	0.4	0.3	0.1	0.3	0.4	0.9
20	0	0.1	0.1	0.1	0.1	0.1	0.4	0.2
SED	*	*	0.262	0.151	0.302	0.234	0.793	0.746
Sig	*	*	0.05	0.080	0.02	0.004	Ns	Ns

% Ramularia top leaves at GS70-80

Treatment	Spring barley GS70-80	Winter barley GS70-80	Winter and spring barley GS81-90
1	2.8	0.1	8.5
2	2.0	0.3	7.1
3	3.1	0.1	5.7
4	1.0	0.0	2.6
5	3.6	0.0	1.2
6	2.6	0.3	10.8
7	1.7	0.1	3.9
8	2.2	0.1	3.9
9	1.5	0.1	4.5
10	2.2	0.2	7.1
11	1.3	0.2	6.7
12	0.8	0.5	3.8
13	1.1	0.1	4.9
14	1.3	0.1	2.4
15	2.0	0.0	3.3
16	2.0	0.3	6.5
17	2.5	0.3	4.2
18	1.9	0.1	7.2
19	3.5	0.2	3.5
20	4.0	0.2	4.1
SED	0.348	0.348	*
Sig	Ns	Ns	*

% Leaf scorch top leaves70-80 spring, GS81-90 Winter

Treatment	Spring GS70-80	Winter GS81-90
1	9.5	35.4
2	10.4	21.8
3	9.7	26.6
4	15.4	17.9
5	11.1	13.9
6	17.2	22.0
7	11.6	17.1
8	11.8	21.0
9	18.7	19.9
10	11.2	23.1
11	8.8	15.7
12	11.6	16.2
13	14.8	21.3
14	12.4	15.6
15	15.4	15.2
16	19.1	22.4
17	10.8	16.6
18	15.7	18.3
19	12.9	17.5
20	14.4	17.4
SED	0.532	*
Sig	Ns	*

% Green leaf Winter barley

Treatment	Top GS49-69	Low GS49-69	Top GS70-80	Low GS70-80	Top GS81-90 Winter & spring	Low GS81-90 Winter & spring
1	99.8	79.3	96.4	57.6	57.0	46.6
2	99.8	83.7	97.6	60.5	70.8	38.5
3	99.9	81.1	97.7	61.9	69.9	40.9
4	99.9	91.0	98.7	69.7	81.2	61.4
5	100.0	83.7	98.1	71.2	83.4	43.1
6	99.8	85.6	98.3	67.2	71.3	31.8
7	99.9	82.3	98.1	72.1	81.2	51.2
8	99.9	84.0	98.3	73.8	76.8	50.5
9	100.0	87.2	98.2	68.4	79.2	58.5
10	99.9	84.8	98.6	71.1	73.8	48.4
11	100.0	91.9	98.3	69.4	79.5	60.8
12	99.9	86.4	98.4	82.6	83.3	54.3
13	99.9	90.6	98.5	78.8	77.6	42.8
14	99.9	86.0	98.7	80.0	83.9	60.4
15	100.0	85.5	98.6	71.9	81.2	57.5
16	100.0	86.9	98.2	69.0	73.1	42.7
17	99.8	89.7	98.1	76.9	79.9	48.6
18	100.0	92.3	98.4	73.2	77.9	53.4
19	99.9	87.2	98.2	71.2	79.8	40.6
20	99.9	90.0	98.3	73.3	80.1	59.2
SED	99.82	99.72	99.75	99.81	99.80	99.78
Sig	Ns	Ns	Ns	0.013	0.007	Ns

Green leaf Spring barley

Treatment	Top GS49-69	Low GS49-69	Top GS70-80	Low GS70-80	Top GS81-90 (all)	Low GS81-90 (all)
1	95.5	73.1	65.5	29.3	57.0	46.6
2	97.5	85.2	82.1	36.5	70.8	38.5
3	95.7	77.2	72.2	35.2	69.9	40.9
4	96.8	82.8	75.1	51.7	81.2	61.4
5	96.1	85.2	69.7	41.9	83.4	43.1
6	97.3	79.5	74.5	24.1	71.3	31.8
7	97.4	79.4	77.7	46.5	81.2	51.2
8	96.9	82.8	77.1	46.9	76.8	50.5
9	96.1	82.3	66.6	37.7	79.2	58.5
10	97.3	83.3	77.8	35.9	73.8	48.4
11	96.5	79.4	81.4	35.1	79.5	60.8
12	97.1	87.4	85.3	64.3	83.3	54.3
13	97.8	86.3	80.8	57.7	77.6	42.8
14	96.6	84.9	80.7	51.0	83.9	60.4
15	96.4	85.6	77.6	43.6	81.2	57.5
16	95.9	80.1	67.0	36.2	73.1	42.7
17	97.3	81.4	79.6	48.3	79.9	48.6
18	97.0	84.4	73.7	35.9	77.9	53.4
19	97.0	86.5	77.1	48.9	79.8	40.6
20	97.0	82.4	75.7	43.6	80.1	59.2
SED	99.82	99.72	99.75	99.81	99.80	99.78
Sig	Ns	Ns	Ns	0.013	0.007	Ns

Yields T/ha, Specific weight

Treatment	Spring T/ha	Winter T/ha	Spring kg/hl	Winter kg/hl
1	5.593	6.768	63.46	56.55
2	5.679	7.590	64.18	56.6
3	5.688	7.338	64.53	57.125
4	6.014	7.785	65.56	57.35
5	5.916	7.808	65.34	57.325
6	5.481	7.646	64.08	57.075
7	5.60	7.864	64.95	57.463
8	5.745	7.739	65.43	56.475
9	5.845	7.503	64.50	57.15
10	5.574	7.493	64.375	57.05
11	5.880	7.657	65.512	58.288
12	6.043	7.796	65.975	57.5
13	5.779	7.213	64.850	56.85
14	5.961	7.800	66.025	57.4
15	6.084	7.834	65.662	57.538
16	5.715	7.376	64.837	57.075
17	5.645	7.746	65.150	57.075
18	5.786	7.494	64.537	56.863
19	5.759	7.453	64.850	57.1
20	5.909	7.578	65.662	56.7
SED treatments	0.1671	0.1671	0.3673	0.3673
Sig	0.009	0.009	0.001	0.001
Sed winter, spring	0.52226	0.52226	2.9721	2.9721
Sig	Ns	Ns	Ns	Ns

5 Appendix 2

Timing of a single treatment in Spring barley

Three spring barley trials carried out in 2002 in the East of Scotland, West of Scotland and Northern Ireland provided a good opportunity to look at differences in fungicide timings over a single season.

	GS25-30	**G39**	**GS45**
1	Nil	Nil	Nil
2	Unix 0.5 kg/ha	Nil	Unix 0.5 kg/ha
3	Opus 0.5 l/ha	Nil	Opus 0.5 l/ha
4	Twist 1.0 l/ha	Nil	Twist 1.0 l/ha
5	Unix 0.5 + Twist 1.0	Nil	Nil
6	Nil	Unix 0.5 + Twist 1.0	Nil
7	Nil	Nil	Unix 0.5 + Twist 1.0
8	Unix 0.5 + Twist 1.0	Nil	Unix 0.5 + Twist 1.0
9	Unix 0.5 + Cropgard 1.0	Nil	Nil
10	Nil	Twist 1.0 + Cropgard 1.0	Nil
11	Nil	Nil	Twist 1.0 + Cropgard 1.0
12	Unix 0.5 + Cropgard 1.0	Nil	Twist 1.0 + Cropgard 1.0
13	Unix 0.5 + Corbel 0.5	Nil	Nil
14	Nil	Twist 1.0 + Corbel 0.5	Nil
15	Nil	Nil	Twist 1.0+ Corbel 0.5
16	Unix 0.5 + Corbel 0.5	Nil	Twist 1.0 + Corbel 0.5
17	Unix 0.5 + Opus 0.5		
18	Nil	Twist 1.0 + Opus 0.5	
19	Nil	Nil	Twist 1.0 + Opus 0.5
20	Unix 0.5 + Opus 0.5	Nil	Twist 1.0 + Opus 0.5

Rhynchosporium development (average of three varieties)

	Gs0-32	GS32-45	GS49-69 top leaves	GS49-69 lower leaves	GS70-80 top leaves	GS70-80 lower leaves	GS81-90 top leaves	GS81-90 lower leaves
1	0.0	0.7	3.2	6.6	3.7	4.3	2.5	0.0
2	0.0	0.0	0.5	1.8	1.3	1.8	0.5	0.7
3	0.0	0.0	0.6	1.9	1.3	1.0	3.2	0.9
4	0.0	0.0	0.9	1.1	1.1	1.0	0.7	0.0
5	0.0	0.0	0.4	0.7	0.8	0.9	1.1	0.0
6	0.0	0.6	1.9	3.3	1.1	1.1	5.7	0.7
7	0.0	1.0	0.8	5.4	2.1	2.3	1.6	0.4
8	0.0	0.0	0.5	1.3	0.3	0.1	0.3	0.0
9	0.0	0.1	0.5	0.3	2.7	1.5	1.7	0.0
10	0.1	0.6	2.1	4.9	2.0	2.3	9.6	2.3
11	0.0	1.1	2.6	6.8	4.5	3.7	2.4	0.8
12	0.0	0.0	0.6	1.6	2.3	2.0	1.0	0.4
13	0.0	0.0	0.5	0.1	0.5	0.6	1.6	0.7
14	0.0	0.8	1.3	1.1	1.4	2.1	2.4	0.0
15	0.1	0.5	1.4	5.1	2.4	2.2	1.4	2.8
16	0.0	0.0	0.4	0.6	0.2	0.2	1.1	0.0
17	0.0	0.0	0.1	0.9	0.8	1.0	1.8	1.3
18	0.1	0.7	1.8	3.6	1.2	1.1	6.6	0.0
19	0.0	0.5	1.0	2.9	1.6	2.1	3.0	1.1
20	0.0	0.0	0.5	0.3	1.1	0.4	1.2	0.0
SED	0.042	0.425	0.321	0.641	0.418	0.564	0.768	*
Sig	NS	Ns	<.001	0.003	0.004	0.038	0.137	*

Barley leaf spots

	% Ramularia	% Ramularia	% Abiotic spots	% Abiotic spots
	GS70-80 top leaves	**GS81-90 top leaves**	**GS70-80 top leaves**	**GS81-90 top leaves**
1	6.0	10.8	7.5	9.4
2	11.1	14.1	10.0	11.1
3	4.8	8.0	3.8	8.5
4	8.8	14.5	8.4	10.2
5	15.1	18.5	5.4	10.7
6	8.9	13.6	4.8	9.7
7	5.9	14.1	6.0	9.8
8	5.9	12.1	5.2	9.5
9	13.6	26.5	8.9	9.7
10	5.7	5.7	3.0	5.4
11	0.8	4.7	1.5	7.4
12	2.2	6.0	1.3	5.3
13	10.5	14.1	8.8	10.3
14	7.4	11.6	8.8	9.0
15	3.5	10.5	12.2	10.4
16	13.0	13.9	5.3	10.9
17	9.2	12.6	4.9	10.3
18	7.2	10.2	4.8	6.5
19	4.0	7.3	0.669	6.6
20	3.0	11.3		5.0
SED	0.655	0.435		0.321
Sig	0.019	0.106	0.069	0.268

% Green leaf area

Treatment	GS49-69 top leaves	GS49-69 bottom leaves	GS70-80 top	GS70-80 bottom	GS81-90 top leaves	GS81-90 bottom leaves
1	96.3	80.7	66.6	32.5	70.8	5.7
2	98.4	91.4	76.3	58.0	43.7	34.9
3	98.6	92.5	91.0	62.2	34.9	23.4
4	98.1	93.7	87.7	45.0	57.2	9.6
5	98.5	94.5	74.2	58.2	64.8	11.1
6	97.4	84.7	74.9	46.5	70.4	10.0
7	97.7	81.0	78.9	31.7	44.4	19.0
8	98.7	92.8	72.4	69.6	60.9	0.1
9	98.6	96.3	82.9	52.2	65.5	10.0
10	97.4	84.1	75.9	52.1	43.6	15.9
11	96.8	84.4	84.0	47.4	45.2	28.1
12	98.1	92.0	86.5	55.5	27.9	34.3
13	98.7	96.8	87.8	68.9	67.2	7.5
14	97.9	92.0	83.7	48.3	49.4	31.5
15	97.0	82.2	79.8	31.7	52.7	20.1
16	98.6	96.6	72.2	68.9	50.1	28.1
17	98.7	92.3	79.5	60.2	54.8	26.2
18	97.1	86.5	81.7	56.7	48.2	0.1
19	98.1	91.3	85.8	59.7	40.5	27.0
20	98.7	96.3	87.9	76.8	38.2	21.6
SED	0.290	0.698	90.8	0.583	0.349	*
Sig	0.055	0.042	Ns		Ns	Ns

Spring barley mean 3 sites 0208 0209 0210

% Rhynchosporium

Treatment	**GS32**	**GS32-45**	**GS49-69 bottom leaves**	**GS49-69 top leaves**	**GS70-80 bottom leaves**	**GS70-80 top leaves**	**GS81-90 bottom leaves**	**GS81-90 top leaves**
1	0.0	0.7	6.6	3.2	4.3	3.7	0.0	2.5
2	0.0	0.0	1.8	0.5	1.8	1.5	0.7	0.5
3	0.0	0.0	1.9	0.6	1.0	1.3	0.9	3.2
4	0.0	0.0	1.1	0.9	1.0	1.1	0.0	0.7
5	0.0	0.0	0.7	0.4	0.9	0.8	0.0	1.1
6	0.0	0.6	3.3	1.9	1.1	1.1	0.7	5.7
7	0.0	1.0	5.4	0.8	2.3	2.1	0.4	1.6
8	0.0	0.0	1.3	0.5	0.1	0.3	0.0	0.3
9	0.0	0.1	0.3	0.5	1.5	2.7	0.0	1.7
10	0.1	0.6	4.9	2.1	2.3	2.0	2.3	9.6
11	0.0	1.1	6.8	2.6	3.7	4.5	0.8	2.4
12	0.0	0.0	1.6	0.6	2.0	2.3	0.4	1.0
13	0.0	0.0	0.1	0.5	0.6	0.5	0.7	1.6
14	0.0	0.8	1.1	1.3	2.1	1.4	0.0	2.4
15	0.1	0.5	5.1	1.4	2.2	2.4	2.8	1.4
16	0.0	0.0	0.6	0.4	0.2	0.2	0.0	1.1
17	0.0	0.0	0.9	0.1	1.0	0.8	1.3	1.8
18	0.1	0.7	3.6	1.8	1.1	1.2	0.0	5.4
19	0.0	0.5	2.9	1.0	2.1	1.6	1.1	3.0
20	0.0	0.0	0.3	0.5	0.4	1.1	0.0	1.2
SED	0.042	0.425	0.641	0.321	0.6	0.418	*	0.768
Sig	Ns	Ns	0.003	<.001	0.04	0.004	*	Ns

Spring barley mean 3 sites 0208 0209 0210

Treatment	T/ha	SPWT kg/hl
1	5.10	60.69
2	5.52	61.60
3	5.88	62.54
4	5.58	61.79
5	5.52	61.36
6	5.36	61.99
7	5.57	62.26
8	5.76	61.68
9	5.63	61.73
10	5.77	62.36
11	5.66	62.86
12	5.90	63.45
13	5.54	61.16
14	5.48	62.26
15	5.50	61.56
16	5.50	61.68
17	5.64	61.42
18	5.59	62.66
19	5.88	62.76
20	6.23	63.32
SED	0.2044	0.559
Sig	0.009	0.001

5 Appendix 3

Rhynchosporium isolates tested for fungicide sensitivity

Year	Trial No.	Location	Site	W/S	Type	Comments*	No. of isolates tested					Total
							Epox	**Flusi**	**Cypro**	**Azoxy**	**MBC**	
2000	0001	QUB	C'creevy	S	var x timing	untreated T1, tested for E (39), F (31), MBC (30); T2 Unix, Amistar, tested isolates for A (34), C (76)	39	31	76	34	30	
	0001	SAC	Annan	S	var x timing	untreated T1, tested for E (1), F (1), MBC (2)	1	1			2	
	0002	SAC	Tibbermore	S	var x timing	untreated T1, tested for E (79), F (21), MBC (16); T2 Unix, Amistar, tested isolates for A (25), C (32)	79	21	31	25	16	
	0003	SAC	Blairnathort	S	Log dose	untreated, Opus, tested for E (52), F (59), MBC (19)	52	59			19	
	0004	SAC	Orwell	W	Log dose	untreated, Opus, tested for E (54), F (58), MBC (19)	54	58			19	
	Annual total						**225**	**170**	**107**	**59**	**86**	**648**
2001	0101	SAC	Tibbermore	W	var x timing	untreated, tested for E (118), F (118), C (109)	118	118	109			
	0102	SAC	Bush	W	var x timing	untreated, tested for E (133), F (133), C (126)	133	133	126			
	0103	SAC	Kirkton	W	Log dose	untreated, Opus, Unix, tested for E (97), F (97), C (91)	97	97	91			
	0104	SAC	Balado	W	Log dose	no Rhyncho isolated						
	0105	SAC	Annan	S	var x timing		17	17	16			
	0106	SAC	Tibbermore	S	var x timing	untreated, tested for E (74), F (74), C (71); QUB trial no Rhyncho	74	74	71			
	0107	SAC	Bush	S	mixture	untreated, tested for E (18), F (18), C (18)	18	18	18			
	Annual total						**457**	**457**	**431**			**1,345**

Year	Trial No.	Location	Site	W/S	Type	Comments*	No. of isolates tested					Total
							Epox	**Flusi**	**Cypro**	**Azoxy**	**MBC**	
2002	0201	SAC	Bush	W	var x timing	untreated, tested for E (151)	151					
	0202	SAC	Annan	W	var x timing	untreated, tested for E (110)	110					
	0203	QUB	C'creevy	W	var x timing	only 10 Rhyncho isolates obtained, not tested						
	0204	SAC	Balmonth	W	mixture	untreated, Opus, tested for E (54)	54					
	0205	SAC	Dunecht	W	mixture	no Rhyncho isolated (leaves dead)						
	0206	SAC	Balmonth	S	mixture	not tested (not requested)						
	0207	SAC	Islabank	S	mixture	not tested (not requested)						
	0208	SAC	Bush	S	sensitivity	untreated, Opus, tested for E (30)	30					
	0209	QUB	C'creevy	S	sensitivity	untreated, Opus, tested for E (26)	26					
	0210	SAC	Annan	S	sensitivity	untreated, Opus, tested for E (31)	31					
	Annual total						**402**					**402**
Grand total							**1,084**	**627**	**538**	**59**	**86**	**2,395**

* E = epoxiconazole, F = flusilazole, MBC = carbendazim, A = azoxystrobin, C = cyprodinil; figures in brackets refer to numbers of isolates tested
Actually tested: total isolates x tests = **2,395**
Proposal: 300 isolates x 3 years = **900**

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7 References

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