PROJECT REPORT No. 282

DEVELOPMENT OF A RATIONALE TO IDENTIFY THE CAUSAL AGENT OF NECROTIC LESIONS IN SPRING BARLEY AND TO IDENTIFY CONTROL MECHANISMS

JUNE 2002

PRICE: £8.50

PROJECT REPORT No. 282

DEVELOPMENT OF A RATIONALE TO IDENTIFY THE CAUSAL AGENT OF NECROTIC LESIONS IN SPRING BARLEY AND TO IDENTIFY CONTROL MECHANISMS

by

S J P OXLEY[1], N D HAVIS[1], K G SUTHERLAND[2], M NUTTALL[3]

[1]SAC Edinburgh, Kings Buildings, West Mains Road, Edinburgh EH9 3JG
[2]SAC Aberdeen, 581 King Street, Aberdeen, AB24 5UD
[3]Morley Research Centre, Morley St Botolph, Wymondham, Norfolk NR18 9DB

This is the final report of a three-year project, which started in March 1999. The work was funded by a grant of £104,189 from HGCA (project no. 2139).

CONTENTS

Abstract

In 1998, spring barley crops in the north of Britain died back before they had reached their potential yield. The reason for the problem was associated with barley leaf spots. Barley leaf spots are caused by a complex of fungi which include *Ramularia collo cygni* and *Leptosphaeria nodorum* (biotic spots) and oxidation damage (abiotic spots), which may be associated with the mildew resistance gene (Mlo gene.

Yield losses and increased screenings are caused by early loss in green leaf area retention on the top two leaves once the crop is starting to flower. Yield losses of 0.28 tonnes/ha were recorded in 2001, but additional losses in quality, in particular screenings can result in poor grain prices for affected crops.

Green leaf area loss is a better measure of damage than a high level of spots, since spot levels may be low if Rhynchosporium has already attacked the top leaves. Late development of spots on green leaves are also unlikely to affect yield.

Varieties vary in their susceptibility to biotic and abiotic spots and the variety Chariot remains the weakest for biotic and abiotic spots. The variety Pewter is more prone to biotic spots than abiotic spots, but no variety is fully resistant to both types of spots. Varieties do show better resistance to abiotic spots than biotic spots however.

Spots develop a few days later in late maturing varieties, so comparing early and late varieties on the same day may give a misleading picture of their susceptibility.

Areas in northern Europe where spots have occurred is on the increase and once established there has not been a season where spots were not important. Currently the problem is more severe in the north of Britain than in East Anglia, but levels of abiotic spots were higher in East Anglia in 2001 than in previous seasons.

Dull wet weather during tillering followed by normal sunny weather at head emergence can result in both biotic and abiotic spots. Rainfall during the tillering and head emergence stages may be more important for biotic spots.

The application of a protectant fungicide comprising any strobilurin fungicide + Opus (epoxiconazole from BASF) at boot stage (Gs45-49) can provide effective protection from spots and maintain green leaf area. Fungicides applied before flag leaf fully emerged (Gs39) will not provide effective protection against leaf spots, and fungicides applied after spots have appeared will not be effective.

Higher fungicide doses will provide longer periods of protection, but the equivalent of 0.4 – 0.5 dose of strobilurin plus 0.4 l/ha Opus is recommended. Unix 0.4-0.5 kg/ha (Syngenta) + Amistar 0.4-0.5 l/ha (Syngenta) is an alternative fungicide at boot stage particularly where severity of spots is low. Chlorothalonil produced an effective delay in spot development but did not achieve the yield benefit seen from strobilurin fungicides. Corbel (BASF) applied at boot stage can reduce green leaf area so should be avoided unless Rhynchosporium or mildew are present at the time of treatment.

Summary

In 1998, spring barley crops in the north of Britain died back before they had reached their potential yield. Not only was yield affected, but the early die-back affected the quality of the grain. A visiting scientist from Germany diagnosed *Ramularia collo cygni* (Ramularia) as the cause of the problem and this word quickly became known in the farming press as the cause. Crop monitoring in Scotland suggests that spots were not observed in surveys up to 1995, but unidentified spot symptoms similar to *Ramularia collo cygni* were recorded in 1996.

This research project was set up to investigate the problem further and started in February 1999. The chief aims are set out below:

- To identify the factors causing necrosis in spring barley
- To identify the environmental conditions under which crops are at risk (i.e. weather and variety)
- To identify fungicides and /or cultural methods to control necrosis
- To determine the effect of necrosis on yield
- Provide a straight-forward advisory message to growers based on the objectives above

To identify the factors causing necrosis in spring barley

It soon became clear that blaming the problem on one fungus Ramularia was incorrect. Certainly Ramularia is associated with the problem, but a vigorous discussion in Bavaria, Germany showed that other causes should be considered. In Bavaria, Ramularia was regularly seen on crops, but the fungus was dismissed as a minor problem taking advantage of crops which were already stressed and had lost green leaf as a result of oxidative damage. Plants by their fixed nature are exposed to the elements all the time, unlike animals who can head for the shade. Plants therefore have established many biochemical pathways to minimise damage from the sun. In Bavaria, sunshine was causing plants to suffer from oxidation damage caused by free oxygen radicals which damage leaves exposed to the sun, whilst parts of leaves in the shade were unaffected. Similar symptoms were seen in crops in the north of Britain. Sun scorch is used to describe this type of leaf damage, but it can be misleading, since it occurs most frequently in countries where dull wet weather is more common than hot sunny conditions. It is currently more common in the northern parts of Europe (Scotland, Ireland, Norway, Germany and Austria) and less important further south (e.g. France, Spain) where you would expect sunshine to be more intense.

In the third year of the project, another fungal spot developed which was identified at *Leptosphaeria nodorum* (*Septoria nodorum*). This fungus is categorised as a biotic spot, but it develops in a different way to Ramularia.

Spots caused by Ramularia and other fungal diseases have been termed biotic spots, whilst spots caused by oxidative stress are termed abiotic spots. In countries affected by the problem, both biotic and abiotic spots can be seen on the leaves. The relative importance of each type will vary upon the variety. In Norway varieties which show signs of physiological spotting are not recommended. As a result of this, biotic spots are more important than abiotic spots. In Scotland and Ireland, both biotic and abiotic spots can be seen and can be difficult to separate. The discussion in Germany continues with the two conflicting arguments that either abiotic spots cause all the damage and biotic spots are irrelevant, or that both types of spots are important. In Austria, spots caused by *Ramularia collo cygni* are thought to be more common than abiotic spots.

During the period of the study, spots were also seen on oats and wheat suggesting the problem can affect other cereals.

Ramularia collo cygni

Although Ramularia can be found on dying leaves early in the season, it is rare to find Ramularia on healthy green leaves during seedling development and tillering stages of growth. Symptoms appear quickly on the top two leaves following head emergence and the start of flowering. A few spots may appear on dying leaves lower down the canopy, but they are more numerous on the top two leaves and sparse on the lower leaves. Leaf symptoms are small brown rectangular spots which are enclosed within the leaf veins. In some varieties a yellow halo is present around the brown lesion. Spots can be seen from both sides of the leaf and they can remain visible after the leaf is dead. When the leaf has died, small white Ramularia spores are seen associated with leaf tissue affected by the spots. Ramularia spots also develop on the awn and the stems as small dark brown spots.

Ramularia symptoms on the leaf resemble net blotch lesions, except net blotch tends to produce longer lesions (in its typical form) or more oval lesions (in the spot form of net blotch).

Leptosphaeria nodorum

In 2001, spots appeared on final leaf four and leaf three before developing on the top two leaves. These spots initially resembled Ramularia, but they were more rounded and not enclosed in the leaf veins. Their development was also different since it is rare for Ramularia to develop first lower down the canopy. The spots were identified as *Leptosphaeria nodorum* (*Septoria nodorum*). Development of the spots shows you must keep an open mind as to the cause of spots and not call all leaf spots which develop late in the season Ramularia.

Abiotic spots

These spots start to appear as leaf below the flag leaf (final leaf 2) emerges. In the variety Chariot, final leaf 2 is fully exposed to the sun following emergence and small yellow spots appear on the leaf. These yellow spots have sometimes been called Mlo spotting. Mlo is the name of the gene which currently provides mildew resistance in many spring barley varieties. These spots turn brown and form a symptom commonly known as pepper spots. Following emergence of the head and the start of flowering, damage to leaf 2 and the flag leaf becomes more severe. Extensive brown lesions occur on the top two leaves, particularly the upper surfaces. Areas of the leaf in the shade are unaffected and the underside of leaves are also unaffected. Later in the season, the damage can occur throughout the leaf and Ramularia spots may also develop on affected leaves.

Pictures of these spots can be seen in Appendix 1 The pictures can also be seen in colour by following the links on the web site www.sac.ac.uk/crops

To identify the environmental conditions under which crops are at risk (i.e. weather and variety)

Field trials were carried out in the north of Britain and in East Anglia. Over the three years of field trials, spots have occurred every year in the north. In East Anglia, spots were rare in the first two seasons, but in 2001, more spots were seen. In East Anglia, abiotic spots were most common and Ramularia generally rare. In the north, both abiotic spots and Ramularia were common in all three seasons. *Leptosphaeria nodorum* spots also developed in 2001. Differences in the levels of biotic and abiotic spots were mostly down to the variety. Chariot was the worst variety to get both biotic and abiotic spots. This fact has undoubtedly resulted in the variety becoming less popular as a major malting spring barley variety. Yield potential also has an influence on spot development. Ironically varieties which achieve the best yields and remain green for a longer period tend to eventually produce more leaf spots than crops which die back prematurely due to root stress, drought or development of other diseases, in particular Rhynchosporium.

Measuring spots as a means of determining the problem is misleading. Measuring loss in green leaf area as a consequence of spots is more meaningful. Since spots become more severe after flowering has started, earlier varieties will show leaf spotting before later maturing varieties. This means assessments on a specific date may show later maturing varieties have fewer spots. Later maturing varieties may be equally affected, but spots may develop a week later once they have reached a specific stage in their maturity. This is an important lesson to take on board when assessing varieties in recommended list trials. As part of the research, several recommended list trials in the north region were assessed for leaf spots and for green leaf area loss. Since it is based on limited data, care must be taken in interpreting the information, but it does show up some interesting differences.

Table 1 Susceptibility of spring barley varieties to barley spotting

Variety	Green leaf area retention	Biotic spots	Abiotic spots	Earliness of ripening	Maturity
Adonis	Good	Poor	Good	*	0
Cellar	Moderate	Poor	Good	5	0
Chalice	Moderate	Poor	Good	6	-1
Chariot	Poor	Poor	Poor	6	-1
Chime	Moderate	Poor	Moderate	*	0
County	Moderate	Poor	Moderate	4	+2
Decanter	Moderate	Moderate	Good	5	0
Harriot	Good	Poor	Moderate	*	-1
Optic	Moderate	Moderate	Good	4	+1
Pewter	Moderate	Poor	Good	5	0
Prisma	Moderate	Poor	Good	6	-2
Riviera	Good	Poor	Moderate	6	0
Saloon	Moderate	Poor	Good	*	+2
Spike	Moderate	Poor	Good	*	0
Spire	Moderate	Moderate	Good	4	+2
Static	Moderate	Moderate	Good	5	0
Tavern	Moderate	Moderate	Moderate		+2

- **Good** – Good resistance to spots or green leaf area retention
- **Moderate** – Moderate resistance to spots or green leaf area retention
- **Poor** – Poor resistance to spots or green leaf area retention
- **Earliness of ripening** 1-9 where a high figure indicates that a variety shows the character to a high degree (from 2002 Recommended list NIAB)
- * no data
- **Maturity** Days + later or – earlier than average (2002 Recommended list Scotland)

Chariot remains the variety with the poorest score for biotic and abiotic spots and loss in green leaf area. Pewter also has a poor score for biotic spots but is not affected so much with abiotic spots. As a result, green leaf area losses are less severe on Pewter than with Chariot. Spire is a late maturing variety so spots would be expected to develop later, and scores for green leaf area retention may be misleading. County (another late maturing variety) has a lower score for green leaf area retention and a poor score for biotic spots.

This information should not sway growers in their choice of variety, since quality is the key component in choosing a variety. The table can be used as a guide to the potential risk of barley spots and their impact on green leaf area should spots occur.

In 2002 harvest year, New Zealand suffered a wet season and spring barley leaf spots were severe prior to harvest. A study of leaf samples showed Ramularia was a key problem, but in some varieties, abiotic spots were also a problem (note in New Zealand, Ramularia is sometimes referred to as Ovularia).

In Scotland and Ireland, weather during the season may also have a bearing on the potential for spot development. Dull wet weather during the tillering stages of growth followed by dry weather with normal sunshine at head emergence can lead to major problems with leaf spots. These weather patterns can lead to an increase in biotic and also abiotic spots. Where weather remains wet, this may favour biotic spots more than abiotic spots.

During the three seasons of trials, we did not have a season were no spots occurred. In fact some areas of Europe saw spots for the first time, and it was thought to be spreading in areas of Austria where it has not appeared before. In order to learn from this lesson, you cannot assume that since you may not currently have had a problem in the past, you cannot suddenly find crops are affected.

Winter barley can be equally affected with biotic spots as spring barley varieties. Abiotic spots are however rare. This may be due to less use of the Mlo gene in winter barely varieties compared to spring barley varieties. Biotic spots have so far occurred so late in the season in the winter crops as to be unimportant economically. In occasional stressed crops of winter barley, spots developed early, but the underlying reason of the stress may be the major problem and the spots a symptom of poor rooting or nutritional stress, particularly low nitrogen. Similar stresses in the spring barley crops can also lead to a higher incidence in spotting which is why malting barley crops may suffer more if nitrogen is limiting.

To identify fungicides and /or cultural methods to control necrosis.

Which fungicide

Fungicides can have an effect on both biotic and abiotic spots. They are, however, more effective at controlling biotic spots than abiotic spots, so even where fungicides have been applied, you can expect leaf spots to occur. They will, however, appear later in the season when the damage they can do to yield is less.

Opus, Opus Team, Amistar, Landmark (BASF), Acanto (Syngenta), Opera (BASF) and Twist (Bayer) all gave good, but not 100%, reduction of necrotic spotting in the field. Of the fungicides tested in the laboratory all gave 99 – 100% control of Ramularia.

Fungicidal tests showed that chlorothalonil e.g. Atlas Cropguard (Nufarm Whyte), Mycoguard (Chiltern), applied at half the manufacturers full recommended dose, could delay the onset of growth of Ramularia for approximately three weeks, but that growth eventually occurred. However, a three week delay in the onset of development of Ramularia on leaves could be long enough to allow crops to ripen sufficiently for the Ramularia to have little effect on yield.

Unix had some effect in controlling necrotic spotting in the field and fungicidal tests showed this fungicide gave good direct control of *Ramularia collo-cygni*, although control was not 100%. Unix in mixture with Amistar achieved good yields, particularly in East Anglian trials where the severity of spots was lower compared to the north.

Punch C (DuPont) was not particularly effective at controlling biotic spots in the field, but achieved good control in the laboratory. The worst fungicide of all was Corbel, which was not effective at controlling biotic spots and it also reduced green leaf area when applied at boot stage under certain conditions. A typical fungicide programme in 1998 when the problem first appeared was Punch C + Corbel (to control mildew and Rhynchosporium). The results indicate this fungicide mixture will give poor control of biotic spots and may lead to an increase in abiotic spots.

Today, to achieve the best reduction in biotic spots, a fungicide mixture comprising a strobilurin fungicide plus the triazole fungicide Opus is recommended. Amistar tends to show weaker activity compared to the other strobilurin fungicides (Kresoxim-methyl in Landmark, Trifloxytrobin in Twist, Pyraclostrobin in Opera and Picoxystrobin in Acanto).

Optimum timing of fungicide treatment

Timing of the strobilurin + Opus mixture to provide effective protection from leaf spots must be before spots appear. Once they have developed, it is too late to achieve an effective reduction. Timing trials showed that boot stage (Gs45-49) or head emergence (Gs59) achieved best reduction in biotic and abiotic leaf spots. For practical reasons, the boot stage timing is recommended rather than ear emergence because some products cannot be applied past boot stage (e.g. Unix, Opus in malting crops) and there is a risk of spots developing before growers have a chance to treat the crop. Timing the fungicide application as the flag leaf is just emerging (Gs37) is too early.

For growers trying to apply a single fungicide to spring barley, a compromise spray timing of flag leaf emerging will be too late to control early mildew and Rhynchosporium and too early for effective protection against barley spots. If growers intend to treat once, it is best to target Rhynchosporium at an earlier timing of Gs25-30, but this will have no effect against barley spots.

Expect leaf spots to appear eventually. All the fungicides can do is delay development of spots during the important grain filling period of growth. Typically, strobilurin fungicides may be effectively controlling many diseases on the leaf surface and one of the first to colonise the clean leaf will be Ramularia. Having effectively controlled all the competition with fungicides, Ramularia can colonise the leaf quickly.

Strobilurin fungicides can also reduce the level of abiotic spots. Since these are not caused by a fungus, the strobilurin fungicides or their formulation may be having an effect on the crop physiology. Growth room experiments showed that the application of an antioxidant to leaves can reduce abiotic spots. This was less successful in the field due to problems with the formulation of the product. Some strobilurin fungicides are formulated with a sunscreen which in growth room experiments did reduce abiotic spots. When the strobilurin was used alone, the differences were less obvious. Dr Tiedemann has researched this area and he suggests that some strobilurin fungicides can help the plant increase its antioxidant pathways.

To determine the effect of necrosis on yield.

Determining the yield loss from leaf spots is not straightforward. Measuring yield loss from not treating the crop at boot stage is easily achieved, but the fungicides applied will be controlling more than the leaf spot diseases. In the last year of the project, the final spray was, by design, either applied too early (Gs37) or at the better timings of boot stage (Gs45-49) and head emergence (Gs59). The only diseases which developed on the top leaves were biotic and abiotic leaf spots. Since all treatments had received the same amount of fungicide, we could measure the impact of spots on yield whilst discounting the influence strobilurin fungicides were having. The figure achieved was 0.28 tonnes/hectare. This is less than the typical yield loss from Rhynchosporium and it must be emphasised that this result was from limited information in one year. In Norway, they have recorded a similar yield penalty due to the biotic spot Ramularia.

The application of Corbel late in the season was detrimental to the development of leaf spots. Trials in 2001 where Corbel was applied to a fungicide mixture resulted in a yield loss of 0.12 t/ha. It is unlikely this reduction will be significant, but it is an indication that using Corbel should be avoided wherever possible at boot stage. Unfortunately if mildew or Rhynchosporium are present at the time you need to spray, you need to apply Corbel to eradicate these more damaging diseases.

Provide a straight-forward advisory message to growers based on the objectives above

- Barley leaf spots are caused by a complex of fungi which include Ramularia (biotic spots) and oxidation damage (abiotic spots)
- Yield losses and increased screenings are caused by early loss in green leaf area retention on the top two leaves once the crop is starting to flower.
- Green leaf area loss is a better measure of damage than a high level of spots.
- Varieties vary in their susceptibility to biotic and abiotic spots.
- No variety is fully resistant to both types of spots
- Spots develop later in later maturing varieties
- Areas where spots have occurred is on the increase and once established there has not been a season where spots were not important
- Dull wet weather during tillering followed by normal sunny weather at head emergence can result in both biotic and abiotic spots. Rainfall during the period may be more important for biotic spots

- Apply a protectant fungicide comprising any strobilurin fungicide + Opus at boot stage for effective protection
- Fungicides applied before Gs39 will not provide effective protection against leaf spots.
- The fungicide must be applied before spots appear and applications following spot development will provide poor control
- Higher fungicide doses will provide longer periods of protection, but the equivalent of 0.4 – 0.5 dose of strobilurin plus 0.4 l/ha Opus is recommended.
- Unix 0.4 kg/ha + Amistar 0.4 l/ha is an alternative fungicide at boot stage particularly where severity of spots is low
- Chlorothalonil achieved an effective delay in spot development but does not achieve the yield benefit seen from strobilurin fungicides
- Corbel applied at boot stage can reduce green leaf area so should be avoided unless Rhynchosporium or mildew are present at the time of treatment.

Introduction

In the early 1980's a number of spring and winter barley varieties in the UK National List/Recommended List variety trials showed varying forms of necrotic spotting on leaves. In some cases the necrosis was so extensive as to render whole leaves brown. A number of factors were assumed to be the cause of the necrosis, including manganese deficiency and a hypersensitive reaction to mildew infection. Extensive research showed neither manganese nor mildew were involved but that conditions such as high temperatures and application of herbicide could induce necrotic responses in glasshouse conditions (Sutherland, 1989). At this time the breeding line of the variety appeared to be important, in particular where the variety Diamant was present in the breeding line.

In the late 1980's and early 1990's, varieties such as Tyne and Derkado produced similar extreme forms of necrosis (Target Spot) in response to rapid temperature fluctuations or low soil pH. The variety Chariot produced its own distinct form of necrotic spotting, in the form of lines of small necrotic flecks within a yellow background. It was assumed this was a similar response to that found by Sutherland (1989), with genetically sensitive varieties reacting to stress.

In the 1997 and 1998 seasons, there was widespread concern by growers over a form of necrotic spotting which appeared in spring barley. The problem occurred throughout the UK, Ireland and northern Europe. In Ireland the varieties Cooper and Optic were particularly affected but in Scotland several varieties including Cooper, Optic, Landlord, Chariot and Prisma were affected. This problem was of particular concern as many growers indicated sudden poor yields in the variety Chariot. There were a number of theories as to the cause of the spotting. In the UK and Ireland, stress spotting, Midas spot and the spot form of net blotch (*Pyrenophora teres*) were suggested (Browne, 1998; Doyle, 1998a; Doyle, 1998b). In Germany the fungus *Ramularia collo-cygni* had been identified (Sachs *et al*, 1998) and high radiation levels causing 'sunburn' were also suggested (Doyle, 1998b; Obst, 1999).

Apart from the work carried out by Sutherland (1989) and the groups in Germany (Sachs et al, 1998; Obst, 1999), little research has been carried out into the cause of necrotic lesions. With newer varieties and an increase in the problem further research was required to identify causal organisms and control methods.

Aim: The aim of the work was to establish the causal factors of the various forms of necrotic spotting in spring barley and to identify a control method.

i) Objectives:

The primary objective of the research was to determine the causes of necrotic spots in barley, and provide guidelines to reduce the associated yield losses.

- To identify the factors causing necrosis in spring barley
- To identify the environmental conditions under which crops are at risk (i.e. weather and variety)
- To identify fungicides and /or cultural methods to control necrosis
- To determine the effect of necrosis on yield
- Provide a straight-forward advisory message to growers based on the objectives above.

The following report has been divided into the following four sections:

1) Laboratory studies carried out to determine the role of Ramularia in the development of necrotic spotting in spring barley.

2) Laboratory studies carried out to determine the role of abiotic spots in the development of necrotic spotting in spring barley

3) Field trials investigating fungicide efficacy, timing and yield loss caused by barley spots

4) Field trials investigating the different responses of varieties to barley spotting

Following these sections, pictures can be seen in Appendix 1. These can also be viewed by following links from www.sac.ac.uk/crops

Section 1 Laboratory studies carried out to determine the role of Ramularia in the development of necrotic spotting in spring barley.

Key author: Karene Sutherland

1. Development of a Key to Necrotic Spotting in Spring barley

Introduction

Different types of necrotic/brown spots develop on the leaves of spring barley varieties, the causes of which can be infection, nutrient deficiency, environmental or varietal. Distinguishing these different types of spotting in the field can be difficult, especially for the uninitiated. The development of a diagnostic key for use in field and glasshouse trials was essential.

Method

The first key was developed by compiling photographs from the SAC slide collection and slides provided and reproduced courtesy of Dr Edelgard Sachs, Biologische Bundesanstalt für Land- und Forstwirtschaft, Institut für Pflanzenschutz in Ackerbau und Grünland, Kleinmachnow, Germany. The photographs were accompanied by brief descriptions of each type of symptom. Further photographs were incorporated during the course of the project from slides taken of symptoms found in the field trials.

Results

An updated version of the diagnostic key is reproduced at the end of this report (see Appendix 1)

Report on a Study Visit to Germany

Introduction

As part of the project, in July 1999 Dr Karene Sutherland visited the laboratory of Dr Edelgard Sachs, Biologische Bundesanstalt für Land- und Forstwirtschaft, Institut für Pflanzenschutz in Ackerbau und Grünland, Kleinmachnow, Germany. Dr Sachs has been working on Ramularia for several years and has developed a method for isolating *Ramularia collo-cygni*. The aims of the visit were to:

a) Visit cereal field trials around the Berlin area in order to learn to identify Ramularia in the field.

b) To obtain laboratory experience in isolating Ramularia from infected cereal leaves.

Methods

Symptoms of Ramularia in the Berlin area of Germany

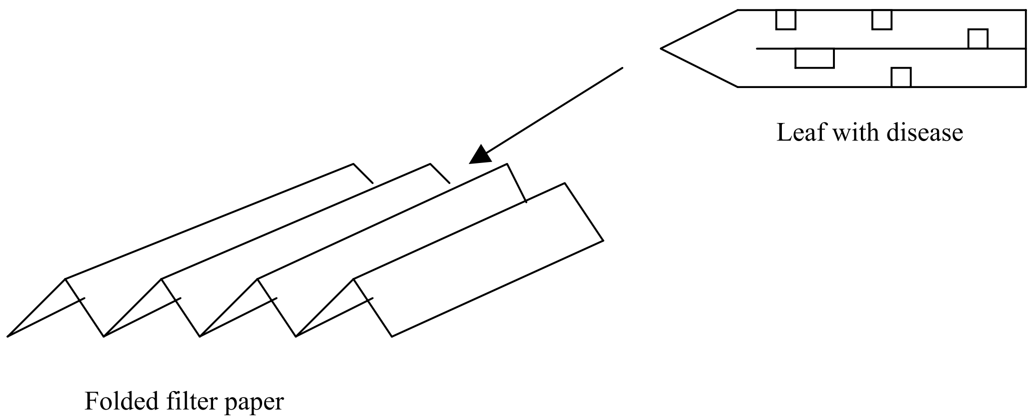
The department of Biologische Bundesanstalt für Land- und Forstwirtschaft, Kleinmachnow, Germany, had two field trial centres, one in Berlin and another twenty miles south of Berlin. There were several trials at each site. Small plot trials were also carried out at Kleinmachnow. Field trials and small plot trials at all three sites were examined visually for the symptoms of Ramularia infection.

2 Isolation and Maintenance of Ramularia collo-cygni

Transport and storage of infected samples

Leaves suspected of being infected with *Ramularia collo-cygni* were removed from plants in the field, placed into polythene bags and taken back to the laboratory as soon as possible. Once in the laboratory leaves were placed within the grooves of folded filter paper or green paper towel, the folds resembling a concertina (Figure 1).

Figure 1. Storage of leaves infected with *Ramularia collo-cygni*

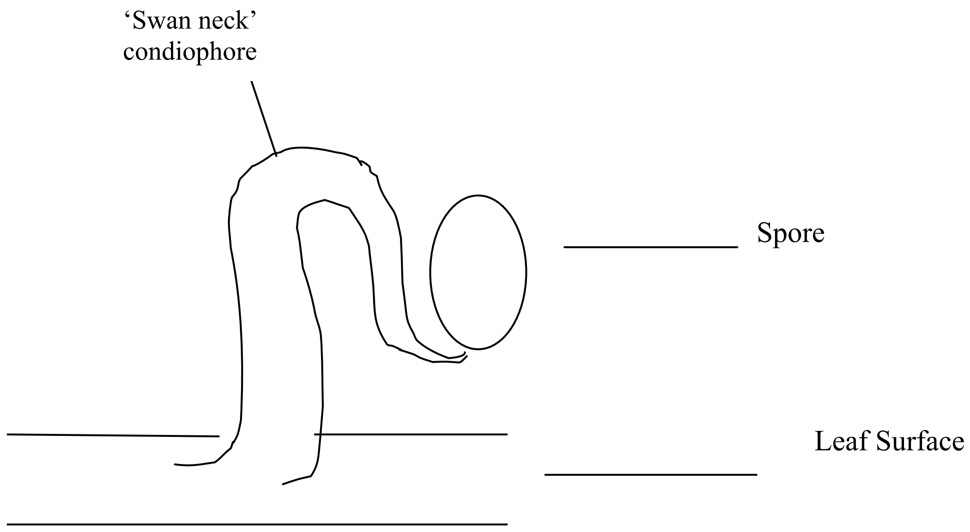


Isolation of *Ramularia collo-cygni*

Suspect leaves were removed from the plant or from the storage filter paper, cut into lengths of 5 – 10 cm and place onto petri-dishes containing tap water agar (+/- chloramphenicol). Leaves were placed lower side upwards, ensuring good contact with the agar. Plates were incubated for 24 to 48 hours (preferably 48 hrs) at room temperature. After 48 hrs incubation, areas of leaves infected with Ramularia turned salmon pink, although this colour change did not always happen.

Where Ramularia was present, examination of leaves under a dissection microscope revealed lines of white conidiophores on and around brown spots. The characteristic 'swan-neck' conidiophores were visible at higher magnifications of 100 – 400 x (Figure 2). Using a dissection microscope and aseptic techniques, single spores were removed from Ramularia colonies using a dissecting needle or scalpel, avoiding touching the leaf surface, which could results in bacterial contamination. Single spores were placed onto V8 juice agar, several per plate. Plates were incubated at 18-20 ^{o}C for 3-4 days.
Ramularia is slow growing and takes several days to establish colonies. The colonies are very sparse and difficult to see on the V8 agar. Individual colonies were transferred onto individual V8 agar plates. After 2-3 weeks colonies should be white or pale pink, with the under surface reddish in colour. Sub-culture isolates onto fresh V8 agar.

Figure 2. 'Swan-neck' conidiophores of *Ramularia collo-cygni*.



Results

The symptoms of *Ramularia collo-cygni* infection on barley crops in Germany took the form of dark brown pepper spots or distinct round, brown spots. On the leaves of some crops the spotting was very sparse whereas other leaves were heavily affected with this spotting. The lines of white conidiophores on the underside of leaves, the presence of which are diagnostic of Ramularia, could not be seen with the naked eye. However, conidiophores could be seen using a hand lens with a magnification of at least 20x. Physiological spotting could sometimes be confused with Ramularia, particularly where levels of infection were very low. In these cases leaves were incubated and isolations taken.

The technique of isolating Ramularia, when present, was relatively straight-forward but success rates were not high. Even where Ramularia colonies were abundant on leaves, often only a small number of colonies grew successfully. Also, isolating Ramularia from older leaves, which were often the most severely infected, resulted in high levels of bacterial or fungal contamination. Therefore, only young or relatively fresh leaves, that is leaves that are not senescing, should be used. Subsequent use of this technique in the UK as part of this project indicated that isolates tended to die off within two or three generations.

3 The Presence of Ramularia on leaf samples within the UK

Introduction

A key to distinguish different types of necrotic lesions on spring barley varieties was developed in 1999 to assist researchers involved in field trials. The use of the key could distinguish the more obvious symptoms that developed within field trials, but often inexperienced assessors required confirmation of symptoms, either visually by a more experienced researcher or by laboratory testing.

Materials and Methods

The second top and flag leaves from plants of field trial plots were sent to the SAC laboratory in Aberdeen. On receipt, leaves were examined visually for symptoms and, where necessary, incubated on tap water agar. After incubating for 48 hours the leaves were examined microscopically for the presence of conidiophores and associated pink colour typical of Ramularia. (Appendix 1 plate 15) Samples from commercial farms were also received and examined.

Results

1999

During the summer of 1999, leaf samples were received from four field trial sites; SAC Aberdeen, Morley Research Centre (Norfolk), Seed Technology (Waterford, Ireland) and Department of Agriculture and Food Cereal Station (Midleton, Co. Cork, Ireland). The samples were all received during June and July, at a time when necrotic lesions were appearing on barley leaves.

In Aberdeen, symptoms on Newgrange appeared in mid-June (Table 1). Large areas of leaves were covered with large, dark brown spots and Target spots (see Appendix 1, plate 23). Later in the season Chariot spotting, brown spots and brown flecking developed. No Ramularia was found pre- or post-incubation.

The samples received from Morley Research Centre showed mainly small brown spots or flecks between the veins (Table 1). The abiotic spotting associated with the variety Chariot was also obvious on many leaves (see Appendix 1, plate 13). No obvious signs of Ramularia were seen pre- or post-incubation.

Fifteen leaf samples from six different varieties were received from Seed Technology in Ireland. Large brown spots were obvious on many leaves, these spots traversing the whole leaf depth. Chariot spotting was also present. Brown pepper spotting was present, often, but not always, associated with yellowing of the surrounding tissue. This pepper spotting was always more severe on the top side of the leaf, irrespective of whether this was the upper or lower side of the leaf, i.e. the side facing the sun was more severely affected than the side shaded from the sun. It was often difficult to distinguish between Chariot spotting and pepper spotting when both symptoms were present simultaneously, but in this case the Chariot spotting was a rusty/brown colour and found between the veins, whereas the pepper spotting was dark brown and found at random over the leaf. Ramularia was seen post-incubation on severely affected leaves of Century only.

Table 1. Necrotic symptoms on spring barley leaves, 1999

Site	**SAC, Aberdeen**	**Morley Research Centre, England**	**Seed Technology, Ireland**	**D.A.F. Cereal Station, co. Cork, Ireland**
No. samples	several	5	15	15
Date received	Late June - late July	June	mid-July	Early June & mid-July
Symptoms	Small brown spots	Brown spots	Large Brown spots	Small brown spots
	Chariot Spot	Chariot Spot	Chariot Spot	Chariot spot
	Brown flecks between veins	Brown flecks between veins	Pepper spotting +/- yellowing	Brown flecks
	Newgrange dark brown lesions & Target spot	Brown Rust		Cooper - large brown spots
Ramularia pre-incubation	No	No	No	Tavern a few lesions
Ramularia post-incubation	No	No	Century, most severely affected leaves only, 1-2 lesions only	NFC 497/9 showed a few lesions with Ramularia post-incubation – similar to short Net blotch streaks
Comments			Symptoms on upper surface always more severe than lower surface	

Fifteen leaf samples from eleven different varieties were received from D.A.F. co. Cork. Symptoms were similar to those received from other sites. The variety Cooper showed distinct large brown spots, called Cooper spot. One of the coded varieties, NFC 497/9, showed short brown streaks similar to the initial symptoms of net blotch. These streaks developed the lines of white conidiophores typical of *Ramularia collo-cygni* post-incubation. Ramularia was not found on any other leaves.

A number of the leaf samples from SAC Aberdeen were taken to Dr Sachs' laboratory in early July during the study visit. None of the symptoms present were identified as Ramularia. One sample of winter barley, taken from a commercial field crop in Aberdeenshire, developed Ramularia after incubation. Symptoms on this winter barley were different to those seen in Germany, distinct brown spots, often with a dark centre.

In late August 1999, a few samples were received from commercial crops in Aberdeenshire, all were from varieties Chalice and Century. Symptoms were unlike any of those seen in field experiments or in Germany - small brown spots, 2-3 mm in length, bounded by the leaf veins giving spots a 'square' appearance. Ramularia was easily identified on these leaves pre-incubation by examination using a dissection microscope - typical white clusters of conidiophores in straight lines across the spot. Under high power microscopy, the characteristic 'swan necks' could be seen. Post-incubation, the numbers of conidiophores present increased.

One sample of spring oats (Variety Amigo) was received showing the 'square' spots. Ramularia conidiophores were numerous on the spots post-incubation.

2001

Two sets of leaf samples were received during early July from SAC Edinburgh, one set from the variety x fungicide trial and one set from the fungicide trial. Samples from the fungicide trial were grouped according to their position on the plant, i.e. Flag leaf, F-1, F-2 and F-3. A few distinct small brown spots were found on a number of leaves within each set but most leaves were showing distinct groups of pale brown/rust coloured 'dashes' between the veins with associated yellowing of the underlying tissue. These symptoms were typical of Chariot (Mlo reaction). No Ramularia was found on the distinct brown spots, pre- or post-incubation.

The symptoms on the leaves from the variety x fungicide trial were identical to those on leaves from the fungicide trial, with the exception of the presence of small brown flecks with pale centres similar to those symptoms produced under severe manganese deficiency.

Discussion

Examination and incubation of leaves from a number of sites indicated that *Ramularia collo-cygni* was not associated with most of the necrotic lesions that develop on spring barley leaves. In the UK, the presence of 'square spots' is indicative of Ramularia. In some varieties, such as Chalice and Century, these can occur alone and are very distinctive. On other varieties the square spots can occur in combination with several other types of necrosis, making the identification of Ramularia more difficult. The symptoms of Ramularia that develop in the UK are different to those that develop in

Germany, the result, perhaps, of different varietal reactions or possible the result of different strain of the pathogen. This difference has yet to be elucidated.

The variety Chariot, develops distinct symptoms associated with the presence of the Mlo gene for mildew resistance. This variety has been showing such symptoms since the mid-1990s and severity is influenced by environmental and soil conditions (Sutherland, unpublished).

The presence of Ramularia on winter barley and oats indicate this problem is not confined to spring barley but is present on all cereals.

4 Sporulation of Ramularia collo-cygni

Introduction

Ramularia collo-cygni was identified as a causal factor in the development of necrotic spots in spring barley crops in Germany, and the fungus was also associated with necrotic lesions in some varieties grown in the UK. In order to determine if Ramularia was the cause of the necrotic spotting, or simply present as a saprophyte on the necrotic tissue, laboratory experiments needed to be carried out to prove Koch's postulates. For this to be achieved, a source of inoculum was needed, namely spores of the Ramularia fungus. The aim was to isolate Ramularia and grow it in sufficient quantities on artificial media to provide large quantities of spores.

Materials and Methods

Ramularia collo-cygni was isolated from the leaves of a commercial winter barley field grown in Aberdeenshire (Scottish isolate). Two further isolates of Ramularia were received from Dr Sachs in Germany, one isolate from Bavaria and one isolate from Austria. All three isolates were inoculated onto V8 agar or PDA and grown at 18^{o}C, 12 hour day, fluorescent lights. The isolates were also grown at 18^{o}C in the dark or at 18^{o}C in black light (Salamati, 2000).

Results

All three isolates of Ramularia proved difficult to maintain on artificial media when grown under fluorescent lights, the isolates dying out after 2-3 generations. No sporulation was achieved under these conditions. No sporulation was achieved when isolates were grown in the dark or under black light.

Discussion

Different fungal species require different light conditions for sporulation to occur (Dhingra & Sinclair, 1987). Some require continuous light, others diurnal light (a period of dark followed by a period of light). In the present study, *Ramularia collo-cygni* failed to sporulate under diurnal light conditions.

Sporulation often occurs under conditions that are a threat to survival of the fungus, that is, the survival of the colony is threatened so the fungus sporulates in an attempt to escape the threat and survive. Growing colonies in the dark has caused sporulation in some cases, but again, Ramularia did not respond to these conditions. Ramularia has been shown to sporulate readily when grown under black light conditions in Norway (Salamati, 2000). However, this was not the case with the three isolates tested in the UK. It is possible the strain of the fungus present in Norway is more receptive to such conditions and more able to sporulate. Since the symptoms that Ramularia produced under field conditions within the UK were different to those seen in Germany, it would suggest a different strain of the fungus is present within the UK.

Physical damage of fungal colonies can induce sporulation. The act of cutting pieces of fungal mycelium from an established colony is sufficient to cause sporulation, but again Ramularia did not respond to this.

Determining the conditions required for sporulation of *Ramularia collo-c*ygni would involve further, extensive research, which was outwith the objectives of this project. This work was not carried any further.

5.Is Ramularia collo-cygni the causal organism of necrotic spotting in spring barley?

Introduction

Ramularia collo-cygni was identified as a causal factor in the development of necrotic spots in spring barley crops in Germany, and the fungus was also associated with necrotic lesions in some crops grown in the UK. It is not known, however, whether Ramularia causes necrotic spotting, or if the fungus is growing as a saprophyte upon the necrotic tissue. In order to determine this, Koch's postulates must be proven. The first part of Koch's postulates has already been achieved, that is, Ramularia has been isolated from leaves and grown on an artificial medium. The second part of Kochs' postulates, inoculating healthy plants with the isolated fungus, development of symptoms and subsequent re-isolation of the fungus, need to be determined.

Materials and Methods

Experiment 1

Seeds of the spring barley varieties Chariot and Optic were sown in Levington compost, nine seeds per pot, two pots per variety, 15 cm pots. Seeds were sown at weekly intervals until the oldest seedlings were six weeks old and the youngest seedlings one week old. The plants were grown in a glasshouse under ambient conditions.

A mycelial suspension of *Ramularia collo-cygni* was prepared by blending a six week old (7 cm diameter) colony of the Scottish isolate of Ramularia in 100 ml of distilled water. The suspension was placed into a hand held plant sprayer and the plants in one pot of each variety from each age group sprayed to run off with the suspension. The remaining plants were sprayed with distilled water. All plants were sealed in poythene bags for seven days to provide a humid atmosphere for infection. The bags were removed after seven days and the plants grown for a further nine weeks until ripe. The plants were watered at regular intervals and examined for the presence of necrotic spots.

Experiment 2

Seedlings of Optic and Chariot were grown as in Experiment 1. Leaves showing necrotic spots typical of Ramularia infection were collected from the field at the end of the growing season. The leaves were incubated in a damp chamber overnight to allow the Ramularia to sporulate. After 24 hours the leaves were washed in 100 ml of distilled water and the resultant spore suspension sprayed on to plants as described in Experiment 1. Untreated plants were sprayed with distilled water. All plants were placed within polythene bags for 7 days to provide a humid atmosphere, the bags removed, the plants were examined for the presence of necrotic spots.

Results

Small, brown, pepper spots appeared on the leaves of both varieties, irrespective of treatment or age of the plants at the time of inoculation. Inoculation with a mycelial suspension of *Ramularia collo-cygni* did not produce the distinct 'square' spots associated with infection by this fungus in the field. Distinct brown spots appeared on the variety Optic, but closer examination of the leaves revealed these spots were the result of mildew infection. Mildew infection occurred on both inoculated and un-inoculated Optic. During the period of growth, the weather turned very warm and temperatures within the glasshouse were in excess of 40^{o}C on some days, despite ventilation.

When this experiment was repeated using a spore suspension of Ramularia, plants of both varieties were severely infected with Rhynchosporium within two weeks of inoculation. No spotting could be seen because of the Rhynchosporium lesions. Plants which were sprayed with distilled water did not develop Rhynchosporium but showed slight pepper spotting. Levels of Rhynchosporium in the field in 2001 were low or absent for most of the season. The leaves used to produce the spore suspension had little or no Rhynchosporium present but there were patches of plants at the edge of the field with quite high levels of Rhynchosporium infection.

Discussion

The pepper spotting that appeared on varieties were the results of the high temperatures within the glasshouse. Such symptoms are often seen on spring barley plants grown in glasshouse conditions and are the result of rapid transpiration followed by closure and collapse of stomatal cells. Square necrotic spots, associated with Ramularia infection, were not seen on either variety. This may have been a consequence of the high temperatures, as temperatures around 20^{o}C are more favourable for development of *Ramularia collo-cygni.* The high temperatures may have killed off the Ramularia spores.

The development of Rhynchosporium on plants inoculated with a spore suspension confirms what was found in field trials in 1999, that is, where a serious foliar disease such as Rhynchosporium is present this outweighs the problem of Ramularia infection.

Ramularia failed to infect spring barley leaves thus it was not possible to prove Kochs' postulates and confirm that *Ramularia collo-cygni* was the cause of the 'square' spots found in field conditions.

6. Effect of fungicides on the growth of Ramularia collo-cygni.

Introduction

Ramularia collo-cygni has been associated with the development of necrotic spots on the leaves of spring barley crops (Sachs *et al*, 1998) A number of fungicides have been shown to reduce necrotic spotting on the leaves of spring barley varieties in field trial situations. However, without detailed examination of leaves it is often difficult to determine if the fungicides have controlled the fungus or, depending on their mode of action, increased the green leaf retention of the variety. The aim of this investigation was to determine the direct effect of fungicides on the growth of *Ramularia collo-cygni*.

Materials and Methods

V8 agar was prepared by placing 200 ml of V8 vegetable juice and 20 g agar (Difco bacto agar) into 800 ml of distilled water. The pH was adjusted to pH 6.0 using sodium hydroxide and sterilised at 15 psi for 15 minutes. Once hand hot the agar was poured into sterile 9cm plastic petri-dishes and allowed to set.

Cultures of *Ramularia collo-cygni*, previously isolated from leaf material, were sub-cultured onto V8 agar and incubated at 18°C for several weeks to provide sufficient inoculum to test against fungicides.

Potato dextrose agar was prepared by placing 39g agar into 1 litre distilled water and autoclaved as per V8 agar. Once cooled to hand hot, the agar was amended with fungicides (Table 2). Fungicide rates used in field trials were half the full manufacturers recommended dose. The equivalents of these rates were used in the tests, assuming the fungicides were applied in a water volume of 200 litres/ha and a petri-dish diameter of 78.5 cm^2. Plugs (9mm diameter) of Ramularia were cut from cultures using a sterile cork borer and place onto the centre of the agar plates, one plug per plate per fungicide. The plates were incubated at 18°C. Colony sizes were measured at regular intervals, the diameter measured in millimetres along two axes, one at right angles to the other. The average of the two measurements was recorded.

Table 2 Rates of fungicide for agar amendment

Product	Application rate (l/ha or kg/ha)	Dilution equivalent (%)	Parts per million equivalent
Strobilurins			
Amistar	0.5	0.25	2500 ppm
Landmark	0.5	0.25	2500 ppm
Twist	1.0	0.5	5000 ppm
Conventional			
Bravo 500	1.0	0.5	5000 ppm
Unix	0.4	0.2	2000 ppm
Opus	0.5	0.25	2500 ppm
Opus Team	0.75	0.375	3750 ppm
Punch C	0.4	0.2	2000 ppm

Results

Colonies were measured every 7 days because of the slow growth of Ramularia. Colonies grown on PDA alone started to grow within a few days of inoculation and continued to grow at a slow rate until 7 weeks after inoculation, when the experiment was terminated. After 7 weeks, colonies were 57.7 mm in diameter (Figure 3 (a), Table 3).

Amending the agar with a half dose of Bravo 500 resulted in a delay in the onset of growth of the Ramularia until 21-28 days after inoculation. Thereafter, growth was slow and by 63 days after inoculation colonies were an average 22.1 mm in diameter (Figure 3 (b)). Colonies were significantly smaller than in the untreated (Table 3). This was the least effective of the fungicide treatments but still had a direct effect on the growth of Ramularia.

Amending the agar with Unix delayed the onset of growth even longer than Bravo 500, no growth appeared until 42 days after inoculation (Figure 3 (c)). Sixty three days after inoculation, colonies of Ramularia were 14.7 mm in diameter, significantly smaller than those produced with Bravo 500 (Table 3).

The strobilurin fungicide Twist allowed slight growth of Ramularia from 35 days after inoculation on one of the five replicates only (Figure 3 (d)). In terms of control of Ramularia this fungicide was effective.

The remaining three triazole fungicides (Opus, Opus Team and Punch C) and the strobilurin fungicides (Amistar and Landmark) all controlled *Ramularia collo-cygni*.

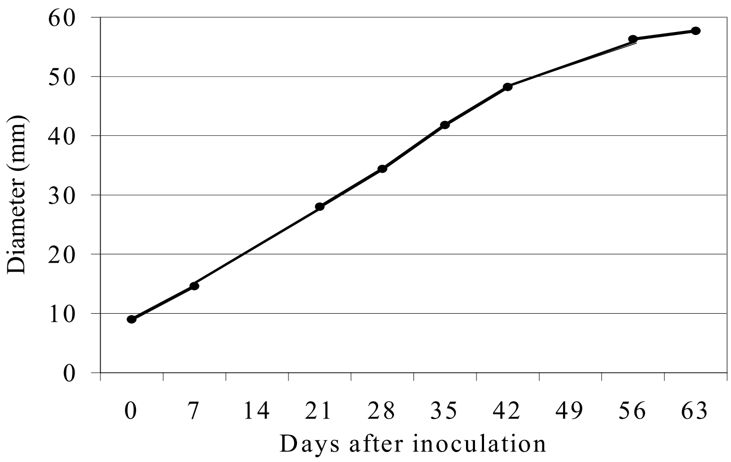
Discussion

Observations from field trials showed that chlorothalonil could reduce necrotic spotting in spring barley crops towards the end of the season. Fungicidal tests showed that Bravo 500, applied at half the manufacturers full recommended dose, could delay the onset of growth of Ramularia for approximately three weeks, but that growth eventually occurred. However, a three week delay in the onset of development of Ramularia on leaves could be long enough to allow crops to ripen sufficiently for the Ramularia to have little effect on yield.

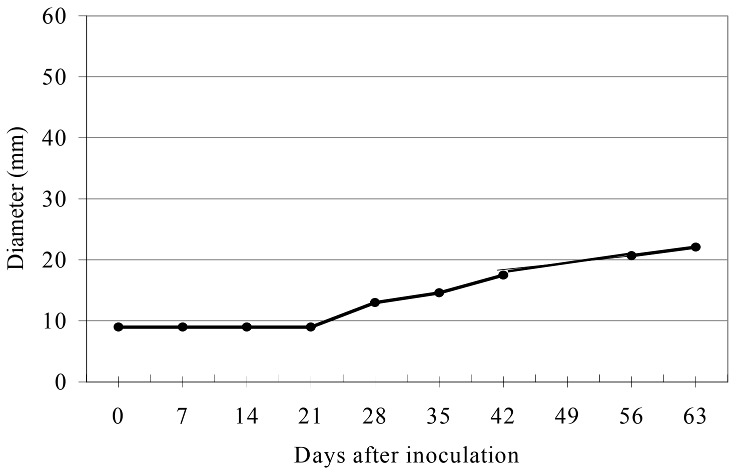
Unix (cyprodinil) gives good control of net blotch and Rhynchosporium and growers tend to apply it early in the season because of its efficacy on *Tapesia yallundae* and *Tapesia acuformis* (W and R strains of eyespot). Results from field trials showed that Unix had some effect in controlling necrotic spotting in the field and fungicidal tests showed this fungicide gave good direct control of *Ramularia collo-cygni*, although control was not 100%.

Figure 3. Effect of fungicides on growth of *Ramularia collo-cygni*

(a) Untreated



(b) Bravo 500



(c) Unix

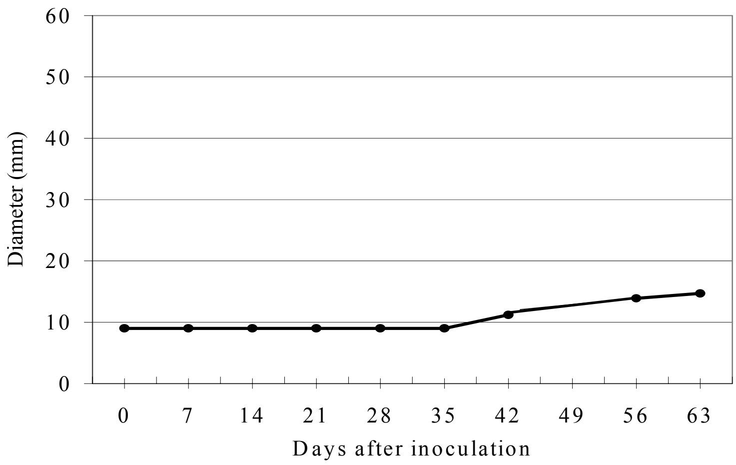
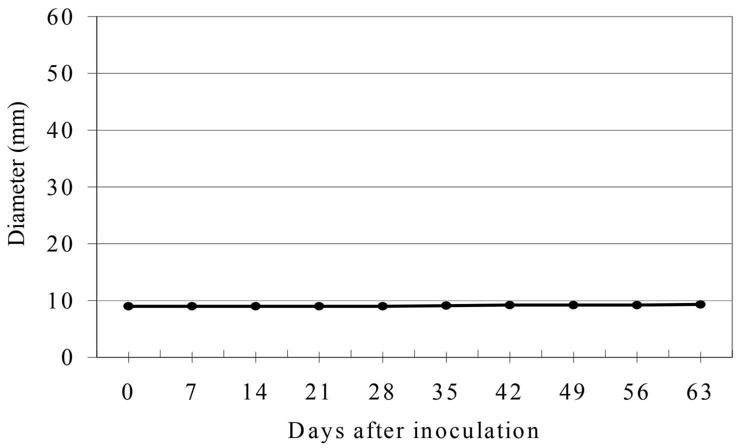
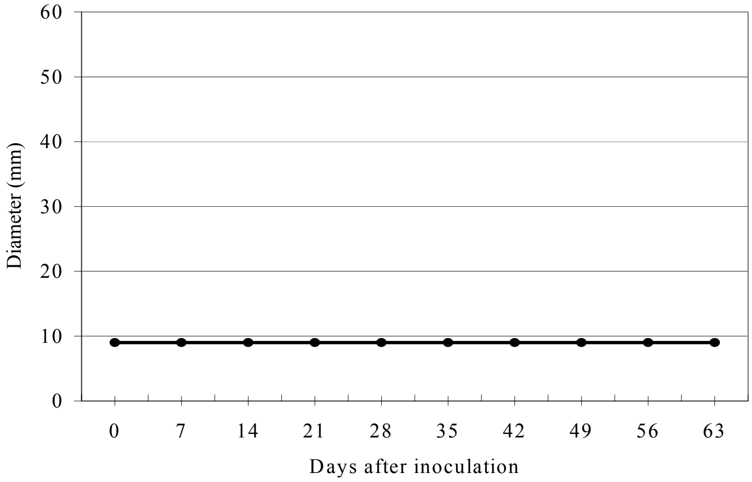


Figure 3. Effect of fungicides on growth of *Ramularia collo-cygni* (cont.)

(d) Twist



(e) Opus, Punch C, Amistar, Landmark, Opus Team



(f) Combined graph

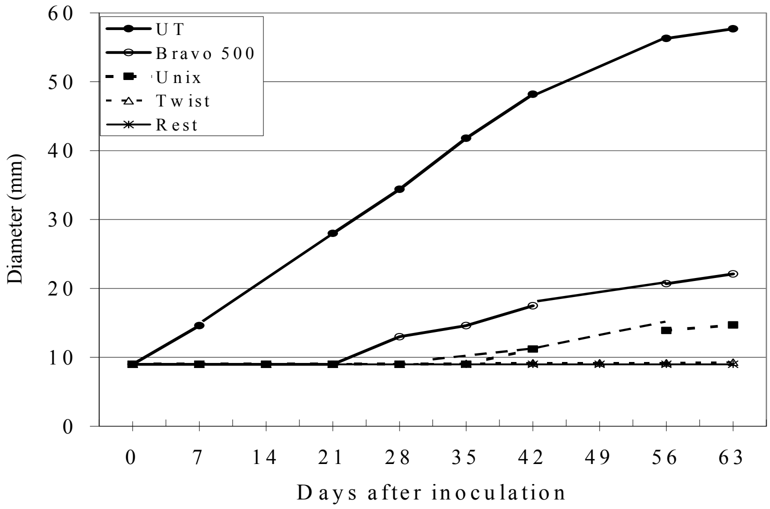


Table 3. Effect of fungicides on the size of *Ramularia collo-cygni* colonies, 63 days after inoculation

Fungicide	Diameter of colony (mm)	
Nil	57.7	a
Bravo 500	22.1	b
Unix	14.7	c
Twist	9.3	d
Opus	9.0	d
Opus Team	9.0	d
Punch C	9.0	d
Landmark	9.0	d
Amistar	9.0	d
SED (31 df)	1.192	
LSD	2.430	
Significance	***	

Punch C was not particularly effective at controlling necrotic spotting in the field but Opus, Opus Team, Amistar, Landmark and Twist all gave good, but not 100%, reduction of necrotic spotting in the field. All of these fungicides, including Punch C, gave 99 – 100% control of Ramularia *in vitro*.

Results suggest that if *Ramularia collo-cygni* is the cause of the 'square' necrotic spots found in spring barley in the field, then the triazole fungicides Opus, Opus Team or Punch C or the strobilurin fungicides Amistar, Landmark or Twist should control the disease, assuming the fungicide is applied prior to infection. Unix would also have some effect on Ramularia in the field. However, Unix cannot be applied after awns peeping (GS 49). Field trials (section 3) showed that applying a fungicide at GS 45 gave good reductions in the levels of necrotic spotting on leaves, but depending on site and season this fungicide could be applied any time from flag leaf emergence (GS 39) to ear half emerged (GS 55). If weather conditions were not conducive to applying a fungicide at GS 45, this could limit the use of Unix.

General Discussion

There is debate amongst researchers in Europe as to the cause of necrotic or brown spotting in spring barley crops. Researchers in Austria, Germany and Norway claim *Ramularia collo-cygni* is the causal organism and that no other factors are involved (Sachs et al, 1998; Huss, 1999; Salamati, 1999). Others, however, claim sunscald is the primary cause of the spotting, or damage, with Ramularia a secondary pathogen (Obst, 1999). In the UK, spotting of various types have been found in spring barley varieties for over 20 years. Until recently, this spotting was the result of environmental and pathogenic pressures on varieties predisposed to spotting due to their breeding pedigrees (Sutherland, 1989).

Much of the spotting that has occurred in the UK over the past five years can still be associated with breeding pedigrees in many varieties, particularly where varieties have been bred with the Mlo gene for mildew resistance, e.g. Chariot. The presence of the Mlo gene in Chariot can cause extensive browning and loss of leaf area on the top two or three leaves post-heading and is the possible cause of much of the yield losses incurred by crops in Scotland in 1997 and 1998. However, a new symptom, the so-called square spot, has appeared in crops late in the season and has been associated with Ramularia infection.

Examination of leaves from a number of sites during 1999 – 2001 revealed that, in most cases, Ramularia was not the cause of brown spotting. Where the square spots were found, however, Ramularia was almost always found pre- or post-incubation, suggesting Ramularia was the cause of these spots. The Ramularia fungus was difficult to maintain on artificial media and sporulation was not achieved. It was not, therefore, possible to complete Koch's postulates and confirm that *Ramularia collo-cygni* was the cause of the square spots on spring barley leaves.

As part of a SEERAD crop survey in 1996, spring barley varieties were examined at watery ripe stage for the presence of diseases on the second top leaf. Samples from a number of sites showed small square spots on the variety Chariot, which at the time were suspected of being the spot form of net blotch (Sutherland, unpublished). Incubation and microscopic examination of these leaves revealed net blotch spores in one case, but in all other cases failed to find the spores of net blotch or any other know pathogen. Similar surveys during 1993 – 1995 did not show this type of symptom. Diagrams made of these symptoms show that the square spot found in 1996 were identical to those found on leaves during this current work. Previous work carried out in the mid-1980s did not find any such square spot symptoms (Sutherland, 1989). If *Ramularia collo-cygni* is the cause of the square spots on spring barley leaves, then previous work suggests this problem first appeared in the summer of 1996.

Further work is required to elucidate if *Ramularia collo-cygni* is the cause of much of the spotting in spring barley and to determine if this has significant effects on yield and yield quality. However, a number of fungicides have been identified that have a direct effect on the growth of this fungus and a report on field studies has shown that a number of these fungicide, e.g. Opus, Amistar, Landmark, Twist, are effective at reducing necrotic spotting on spring barley leaves in field conditions.

Section 2 Laboratory studies carried out to determine the role of abiotic spots in the development of necrotic spotting in spring barley

Key author: Neil Havis

1. Growth room experiments

Introduction

Observations from field trials and previous work indicated that necrotic spots due to a physiological effect appeared on a number of varieties. Detailed studies of spot formation in Germany implicated high radiation levels as a potential cause of leaf necrosis. (Obst *et al.* 1995). High radiation levels are known to lead to the formation of potentially damaging free radicals in the leaf. Further work in controlled environments and field trials showed that a sudden increase in temperature accompanied by high light intensity can lead to a significant stress response in susceptible varieties. Fungicides and other compounds with antioxidant activity have been shown to reduce the formation of necrotic spots. (Wu and Von Tiedemann, 2002). An experiment was undertaken at SAC Edinburgh to investigate the factors which lead to spot formation and the ways in which spots could be controlled or reduced.

Materials and Methods

Two varieties were selected based on their differing susceptibility to necrotic spotting. Pots of Spring barley (cv. Chariot and Optic) were sown into Fisons Levington compost in 18 cm pots on the 7th of December 1999. Eight seeds were sown per pot and seedlings thinned to six per pot after germination. Plants were grown in a controlled environment chamber under 400W mercury lights with a regime of 16 hours light and 8 hours dark. At the time of emergence light levels at seedling height were equivalent to 150 PAR ($\mu E\ m^{-2}\ s^{-1}$).

A number of treatments were selected to alleviate or eliminate the formation of spots. The treatments are outlined in Table 1.

Table 1 Treatments in growth room experiments

Code	Variety	Treatment
C1	Chariot	Untreated – Normal growth room lights
C2	Chariot	One layer of shading from GS 32-39
C3	Chariot	Double shading from GS 32-39
C4	Chariot	Sprayed with Nufilm P at GS 37
C5	Chariot	Sprayed with Zeneca 'sunscreen' at GS 37
C6	Chariot	Sprayed with Amistar at GS 37
C7	Chariot	Sprayed with α-tocopherol at weekly intervals from GS 32 on
C8	Chariot	Sprayed with α-tocopherol at GS 37
C9	Chariot	Normal light then increased light for 7 days at GS 39
C10	Chariot	One layer of shading at GS 37 then increased light for 7 days at GS 39
C11	Chariot	Double shading at GS 37 then increased light for 7 days at Gs 39
O1	Optic	Untreated – Normal growth room lights
O2	Optic	One layer of shading from GS 32-39
O3	Optic	Double shading from GS 32-39
O4	Optic	Sprayed with Nufilm P at GS 37
O5	Optic	Sprayed with Zeneca 'sunscreen' at GS 37
O6	Optic	Sprayed with Amistar at GS 37
O7	Optic	Sprayed with α-tocopherol at weekly intervals from GS 32 on
O8	Optic	Sprayed with α-tocopherol at GS 37
O9	Optic	Normal light then increased light for 7 days at GS 39
O10	Optic	One layer of shading at GS 37 then increased light for 7 days at GS 39
O11	Optic	Double shading at GS 37 then increased light for 7 days at Gs 39

Experience in previous work has indicted that field rate applications of fungicides can be phytotoxic in controlled environments, therefore Amistar, NuFilm P and the Zeneca sunscreen were applied at 1/10 of the normal field rate. ∝-tocopherol was solubilised in ethanol and applied at a rate equivalent to 5mls/litre. All sprays were applied in a volume of 200 mls and the leaves sprayed until run off (Shephard, 1987).

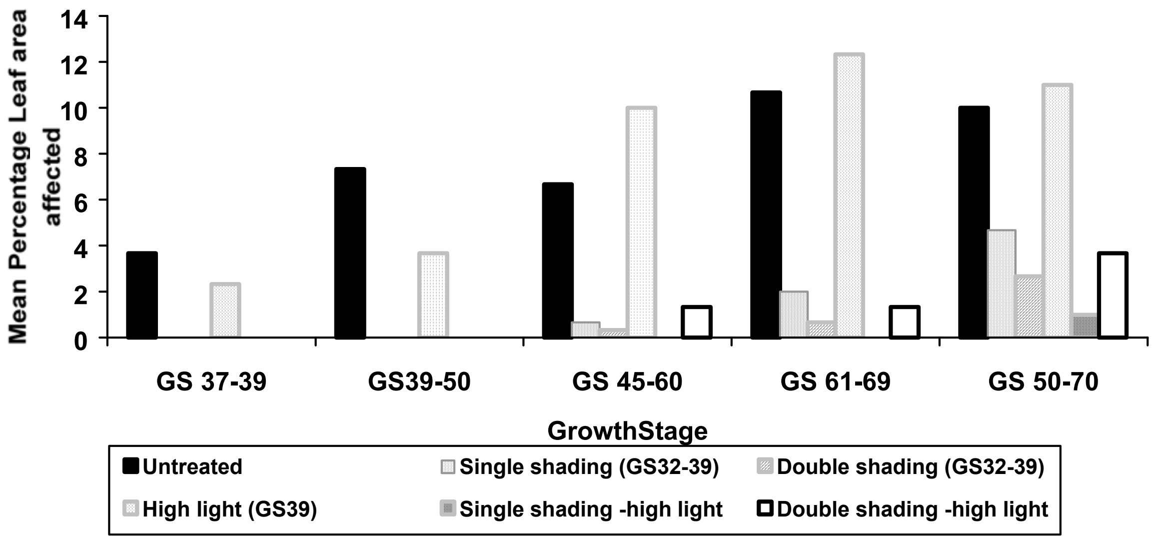
Each treatment was replicated in three pots. Light levels at canopy height were monitored throughout the experiment. Green mesh shading material was used to simulate shading over the plants. A single layer of the shading reduced light intensity by 62%. A double layer of shading reduced light intensity by 79%. Symptoms of manganese deficiency were observed on the older leaves of some treatments prior to the application of the spray treatments. Individual leaf layers were assessed for spot formation from Growth Stage 37 onwards by assessing three leaves of each leaf layer at random within each pot.

Results

Scores for necrosis on individual leaf layers are given in Appendix 2 and plates depicting the experimental layout and spots observed are in Appendix 1, plates 27—30. Spots appeared on some of the plants in early February and levels continued to rise until late March when the unfortunate contamination of the growth room by powdery mildew (*Blumeria graminis)* lead to the conclusion of the experiment.

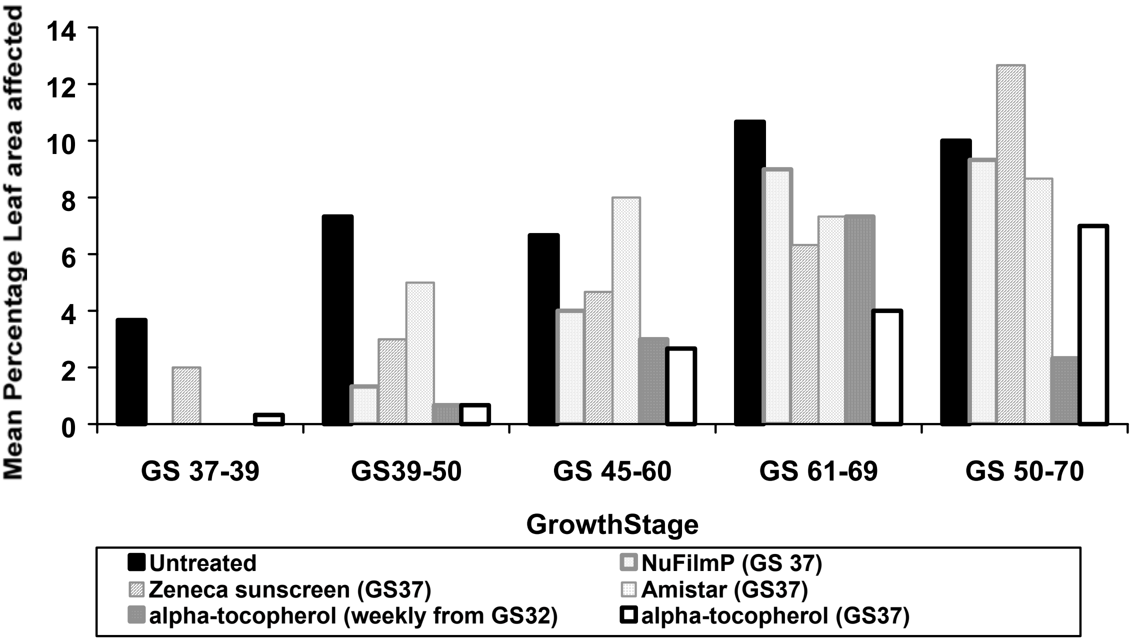
Results for the flag leaf on the Optic pots indicate that the untreated plants and those treated with high light intensities gave the highest level of spots (Figure 1).

Figure 1 % Necrotic spots - cv Optic Flag Leaf



On the last assessment date when significant differences between the treatment and the control were observed (mid March), the greatest control of necrosis was given by the treatments which involved shading the plants. In some cases this control was nearly absolute (Single shading-high light). Of the chemical treatments used, a single spray of the antioxidant compound α-tocopherol gave the biggest reduction in spots on the leaf (62%). See Figure2

Figure 2 Necrotic spots - cv Optic Flag Leaf



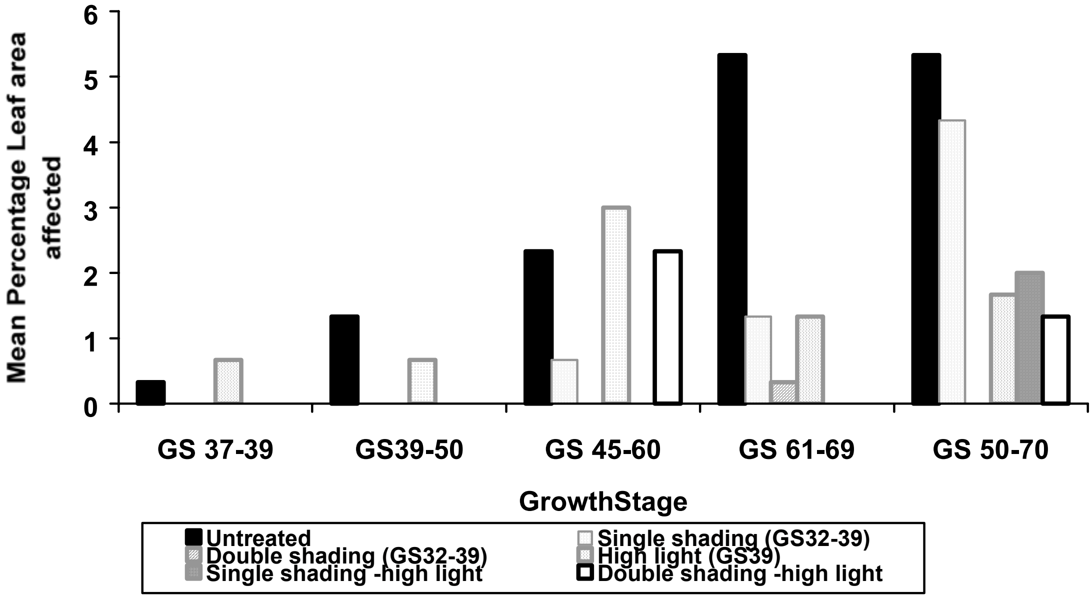
A similar pattern was observed on the F-1 layer. Levels of spots were similar to flag leaves. The treatments which included shading again gave the biggest reduction, ranging from 60% to 88%). Of the chemical treatments used, the ones containing the antioxidant compound again gave the best control (41 and 52% respectively). By mid March these were the only chemical treatments which gave a statistically significant control of spots compared to the control.

Significant differences between the treatments and the untreated plants were observed on the Leaf F-2 layer throughout the experiment. Again the shading treatments gave the biggest reduction in spot formation. On this leaf layer the chemical treatments performed less efficiently with the Zeneca sunscreen giving a small, insignificant increase in spots by the end of the experiment. On this leaf layer the weekly application of α-tocopherol was the most effective chemical (spots levels were reduced by 46%).

The general pattern for Optic was repeated again on leaf F-3. Shading treatments again outperforming chemical ones. The most effective shading treatment was the double shading. By the end of the experiment spot levels were reduced by 60%. Of the chemicals examined the single antioxidant treatment was the most effective (44% reduction in spots).

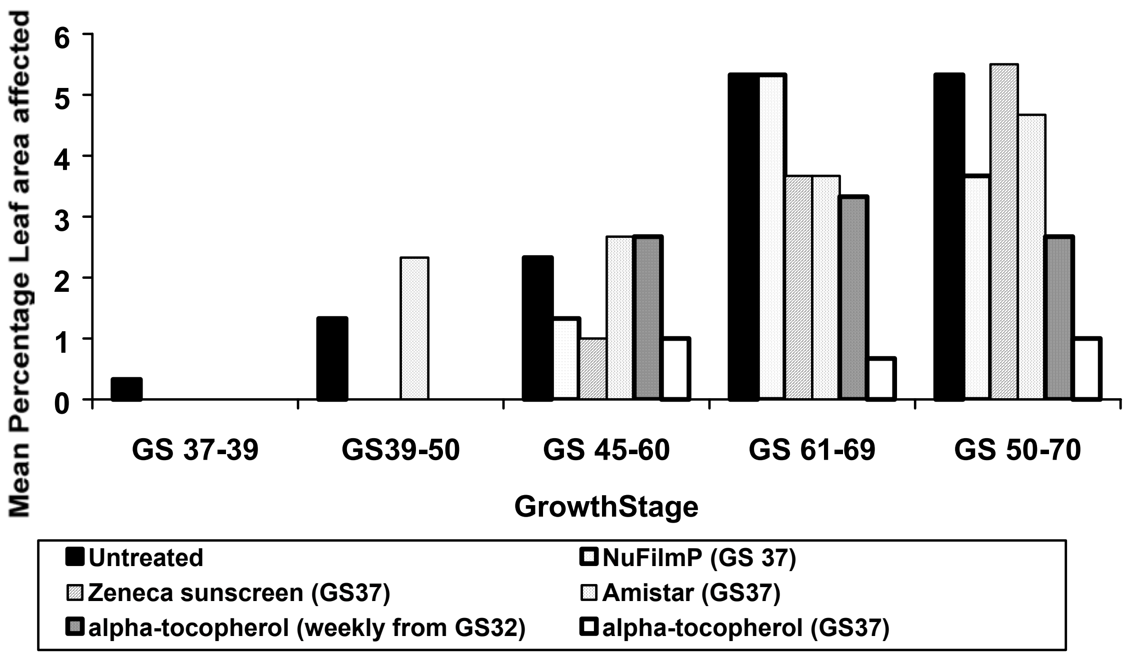
When the flag leaf was examined in the Chariot pots the shading treatments were seen to give the best control of necrosis (Figure 3).

Figure 3 Necrotic spots - cv Chariot Flag Leaf



The double shading treatments gave absolute control. The most effective chemical control was a single application of ∝-tocopherol (81% at the last assessment date) See figure 4.

Figure 4 Necrotic spots - cv Chariot Flag Leaf



Although the overall significance level of the results was poor there were still some significant differences between the most effective treatments and the untreated pots. The Zeneca sunscreen compound was the only treatment that failed to give any control of necrosis on the flag leaf.

A similar pattern was seen on leaf F-1, where again the top control was given by the double shading treatment. This control dropped from 80% to 45 % in the last week of the experiment. The best chemical examined was the antioxidant ∝-tocopherol. Control was only moderate at best though. The same pattern was seen on leaf F-2 and leaf F-3. The majority of chemical treatments performed poorly on these leaf layers and some gave a small increase.

2. Field trial experiments

Materials and Methods

A field trial was carried out at SAC Edinburgh in 1999 to examine the influence of shading on necrotic spot formation. Spring barley (cv. Chariot) was sown in nine 20 metre strips. Three treatment regimes were carried out on the strips. Treatments are outlined in Table 2.

Table 2 Treatments in shading field trial

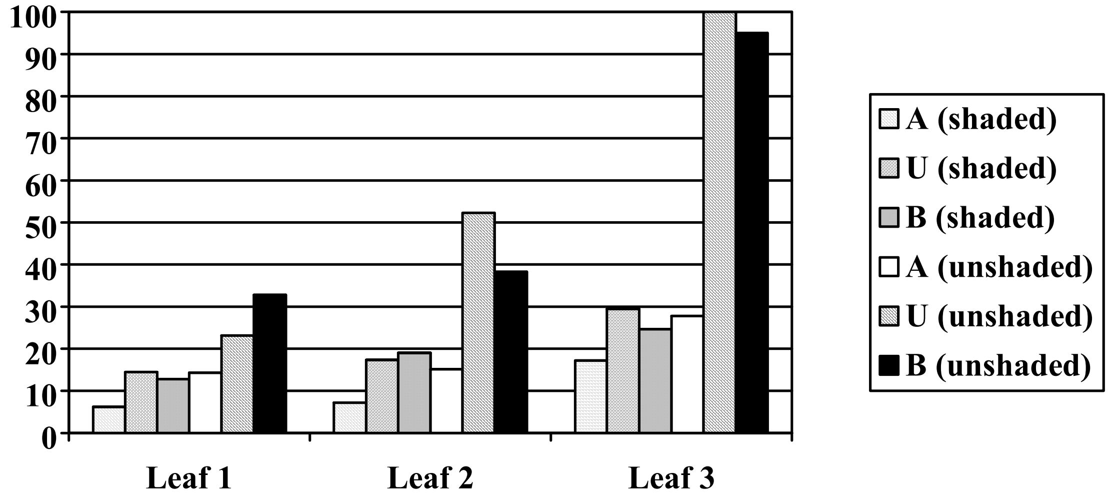
Code	Plot Numbers	Gs 39-41
U	4,5,6	Nil
A	1,2,3	Amistar 0.3 + Sanction 0.1
B	7,8,9	Cheetah Super 1.5 l/ha

After spray applications a screen was erected across the width of the trial subdividing the plots into two. The plots were assessed for disease and also necrosis and chlorosis over the rest of the growing season. Screens reduced light intensity by 75 %.

Results

At the first assessment date, one week after spraying there were only slight differences between the plots in Rhynchosporium levels and chlorosis. Necrosis levels were higher in Treatment B compared to the control both inside and outside of the shades (100% and 46% respectively). As the trial progressed it became apparent that the herbicide had damaged the crop and also left it exposed to disease. This pattern was consistent in and outside of the shades. Necrosis levels under the shades appeared to be increasing at a much slower rate than the levels outside the shades. An increase of over 100 % percent was observed in untreated plots outside the shades between Growth stage 62 and 72 (Appendix 2). During the same period, necrosis levels in the untreated plots under the shades stayed relatively constant. A detailed assessment of the leaves late in the trial (Growth stage 82; Figure 5) showed that on the Flag leaf the shades had significantly reduced the necrotic spots within each treatment.

Figure 5 Necrosis in leaf layers - Late July



On untreated plots shading halved necrosis levels (Appendix 2). This pattern was repeated on the second leaf (F-1) layer. The Amistar treatment gave the biggest reduction in spotting compared to the control. Under the shades Amistar gave a 50% reduction in necrosis on the top two leaf layers. Outside the shades the reduction was more dramatic as levels in the untreated were even higher e.g. on leaf 2 necrosis levels were reduced from 51% of leaf area to 15%. A late season assessment of Ramularia in the trial showed that the disease was present at greater levels outside the shades. Under the low light intensity the Ramularia lesions had a more variable appearance.

General Discussion

The appearance of necrotic spots has been related to a number of factors including physiological reactions to stress factors and attack by fungal pathogens. Necrosis levels as high as 60% on the uppermost leaf layers has been reported in some sensitive cultivars (Lyons *et al.,* 1999)

Previous work carried out in Europe indicates that the production of necrotic spots in barley can be alleviated by the use of various fugicdes (Obst *et al.,* 1996, Wu and Von Tiedemann 2002). The results from our experiments in the growth chamber showed that strobilurin fungicdes gave relatively poor control of spot formation in these conditions. However the timing of fungicides to control spots is of critical importance. A single spray at Gs 39 may not be the ideal time to give spot control. The level of control given on Optic and Chariot is different. This observation concurs with work done on varieties in Germany with differing susceptibilities to necrotic spot formation (Wu and Von Tiedemann 2002). In their studies strobilurins had their greatest effect on varieties which were more susceptible to spot formation. In the controlled experiment levels of necrosis were higher in Optic than Chariot (Appendix 2). This contrasts with the situation in the field. Under more natural environmental conditions necrosis levels were higher in Chariot than Optic (see Section 4). This could be due to the effect of other stress factors on the crop in field conditions..

Under field conditions the strobilurin fungicide, Amistar, gave better control of spot formation. The reasons for this difference are not clear but may be related to the higher light intensities in the controlled environment experiment. (Highest recorded value at trials site in this year was 188 PAR (μE m^{-2} s^{-1}) compared with 298 PAR (μE m^{-2} s^{-1}) in the growth room. Spot formation is known to be influenced greatly by environmental factors and can also vary from season to season within a variety. The dose rate of Amistar was also reduced in the glasshouse experiment to avoid any possible phytotoxic problems and this may also have contributed to the reduced control observed.

The most striking observation in these experiments was the elimination of spots by the use of screens. Under controlled conditions double shading (79 % reduction in light intensity) gave complete control of spot formation. These observations are consistent with other work (Doyle, 1998) and anecdotal evidence from growers and researchers which indicated that leaf layers which were shaded were generally free from spots. Results from the field experiment also indicate that spots formation can be reduced by a magnitude of 2 by the presence of the screens. Earlier in the trial, the reduction in necrosis was even more apparent. In the field trial the major increase in necrosis in the crop took place after the ear had fully emerged.

Reduced light intensities were also seen to affect the expression of disease on the crop e.g. *Ramularia collo – cygni* (see Appendix 2). This further complicates the issue of spot/pathogen identification. *Ramularia* is known to give larger spots on winter barley in Austria (H Huss, personal *communication*). Physiological spotting in plants is associated with an increase in active oxygen species (Wu and Von Tiedemann, 2002). There is evidence from other species in the *Ramularia* genus, that these fungi can also produce active oxygen species on the surface of the host plant (Glumova *et al.,* 1994). If *Ramularia collo-cygni also* produces free radicals *then* this may help to explain to difficulty in differentiating between physiological spots and pathological spots in spring barley crops.

References

Doyle, A. 1998. In the fields. Irish Farmers Journal , July 4; 15-16.

Glumova, N.V., Guzhova, N.V., Merzylak, M.N. and Chivkuvona, O.B. 1994. Possible involvement of oxygen radicals in the damage of coriander plants by *Ramularia coriandri.* 41 (1): 114-117.

Lyons, T., Ollerenshaw, J.A., and Barnes, J.D. 1999. Impacts of ozone on *Plantago major*: Apoplastci and symplastic antioxidant status. New Phytologist 141: 253-263.

Obst, A., Baumer, M., and Huber, G. 1995. Leaf blotch of non-parasitic origin on barley – Does the damaging occurrence increase ? Gesunde Pflanze 47: 308-314.

Shephard, M.C. 1987. Screening for fungicides. Annual Review of Plant Pathology 25 : 189-206.

Wu, Y. X., and von Tiedemann, A. 2002. Evidence for oxidative stress involved in physiological spot formation in winter and spring barley. Phytopathology 92: 145-155.

Section 3 Field trials investigating fungicide efficacy, timing and yield loss caused by barley spots

Key author: Simon Oxley

Materials and Methods

Field trials were carried out, to determine fungicide timing and fungicide control of necrotic spots. The trials were also developed in the final year to determine the yield loss from spots.

1. To identify a fungicide control programme for necrotic lesions in spring barley

Eight field trials were carried out in Norfolk, Borders, Lothians, Aberdeenshire in 1999, 2000 and 2001. The variety Chariot was used in all trials and a range of 20 fungicide treatments were used each year (Tables 1, 2, and 3). Trials were sown as randomised blocks, plot size 40 m^2, 4 replicates. Plots were sown using an Oyjord drill. Except for fungicide treatments, all trials received standard agronomic inputs for the area.

In all trials the percentage leaf area infected (LAI) by each foliar disease and necrotic spots was assessed on a whole plot basis prior to significant necrotic spot development and then on a leaf by leaf basis, 10 plants/plot. Plots were combined using a small plot combine and yields adjusted to 85% dry matter. Specific weights and screening fractions were determined. Data was analysed using the ANOVA package of Minitab and/or Genstat.

Table 1 Fungicide treatments used to identify the most appropriate programme for control of necrotic lesions in spring barley 1999 (three trials)

	GS25-30	GS32-33	GS37-39	GS39-45	GS45	GS59
1	Nil	Nil	Nil	Nil	Nil	Nil
2	Punch C 0.625 + Corbel 0.75	Nil	Opus Team 1.5	Nil	Tilt 0.5 + Torch 1.0	Nil
3	Amistar pro 2.0 + Unix 0.67	Nil	Nil	Nil	Amistar pro 2.0	Nil
4	Amistar 1.0	Nil	Nil	Nil	Nil	Nil
5	Nil	Amistar 1.0	Nil	Nil	Nil	Nil
6	Nil	Nil	Amistar 1.0	Nil	Nil	Nil
7	Nil	Nil	Nil	Nil	Amistar 1.0	Nil
8	Nil	Nil	Nil	Nil	Nil	Amistar 1.0
9	Punch C 0.4	Nil	Nil	Punch C 0.4	Nil	Nil
10	Opus 0.5	Nil	Nil	Opus 0.5	Nil	Nil
11	Bravocarb 2.0	Nil	Nil	Bravocarb 2.0	Nil	Nil
12	Landmark 0.5	Nil	Nil	Landmark 0.5	Nil	Nil
13	Amistar 0.5	Nil	Nil	Amistar 0.5	Nil	Nil
14	DUKF9903 1.5	Nil	Nil	DUKF9903 1.5	Nil	Nil
15	279 + propiconazole 1.0	Nil	Nil	279 + propiconazole 1.0	Nil	Nil
16	279 + Propiconazole 0.5	Nil	Nil	279 + Propiconazole 0.5	Nil	Nil
17	Tank & equipment cleaner 200g in 200 litres water /ha	Nil	Nil	Tank & equipment cleaner 200g per 200 litres water/ha	Nil	Nil
18	LI700 1 litre in 200 litres water/ha	Nil	Nil	LI700 1 litre in 200 litres water /ha	Nil	Nil
19	Amistar 0.5 + Unix 0.4 kg	Nil	Nil	Amistar 0.5 + Unix 0.4kg	Nil	Nil
20	Punch C 0.4 + LI7001 litre in 200 litres water /ha	Nil	Nil	Punch C 0.4 + LI7001 litre in 200 litres water /ha	Nil	Nil

Table 2 Treatments used to identify a fungicide control programme for necrotic lesions in spring barley 2000 (Two trials)

Code	GS25-30	GS32-33	GS37-39	GS39-45	GS59
1	Nil	Nil	Nil	Nil	Nil
2	Punch C 0.625 + Corbel 0.75 + Unix 0.67	Nil		Opus Team 1.5 (+ Unix 0.67 if Rhynchosporium present)*	Nil
3	Amistar pro 2.0 + Unix 0.67	Nil	Nil	Amistar Pro 2.0 (+ Unix 0.67 if Rhynchosporium present)*	Nil
4	Amistar 1.0	Nil	Nil	Nil	Nil
5	Nil	Amistar 1.0	Nil	Nil	Nil
6	Nil	Nil	Amistar 1.0	Nil	Nil
7	Nil	Nil	Nil	Amistar 1.0	Nil
8	Nil	Nil	Nil	Nil	Amistar 1.0
9	Punch C 0.4	Nil	Nil	Punch C 0.4	Nil
10	Opus 0.5	Nil	Nil	Opus 0.5	Nil
11	Atlas CropGard 2.0	Nil	Nil	Atlas CropGard 2.0	Nil
12	Landmark 0.5	Nil	Nil	Landmark 0.5	Nil
13	Amistar 0.5	Nil	Nil	Amistar 0.5	Nil
14	Acanto 0.5	Nil	Nil	Acanto 0.5	Nil
15	Twist 1.0 + Opus 0.5	Nil	Nil	Twist 1.0 + Opus 0.5	Nil
16	Opera 0.75	Nil	Nil	Opera 0.75	Nil
17	Tank & equipment cleaner 200g in 200 litres water /ha	Nil	Nil	Tank & equipment cleaner 200g per 200 litres water/ha	Nil
18	Nu Film P 180 mls	Nil	Nil	NuFilm P 180 mls	Nil
19	Amistar 0.5 + Unix 0.4 kg	Nil	Nil	Amistar 0.5 + Unix 0.4kg	Nil
20	Punch C 0.4 + NuFilm P 180 mls	Nil	Nil	Punch C 0.4 + NuFilm P 180 mls	Nil

Table 3 Treatments used to identify a fungicide control programme for necrotic lesions in spring , 2001 (three trials)

	GS 25-30	GS 32-33	GS 37	GS 45	GS 59
1	Nil	Nil	Nil	Nil	Nil
2	Amistar pro 2.0 +Unix 0.67	-	Amistar Pro 2.0 + Unix 0.67	-	-
3	Amistar pro 2.0 + Unix 0.67	-	-	Amistar Pro 2.0 + Unix 0.67	-
4	Amistar pro 2.0 + Unix 0.67	-	-	-	Amistar Pro 2.0 + Unix 0.67
5	Amistar 1.0	-	-	-	-
6	-	Amistar 1.0	-	-	-
7	-	-	Amistar 1.0	-	-
8	-	-	-	Amistar 1.0	-
9	-	-	-	-	Amistar 1.0
10	Opus 0.5	-	-	Opus 0.5	-
11	Atlas CropGard 2.0	-	-	Atlas CropgGard 2.0	-
12	Landmark 0.5	-	-	Landmark 0.5	-
13	Amistar 0.5	-	-	Amistar 0.5	-
14	Acanto 0.5	-	-	Acanto 0.5	-
15	Twist 1.0 + Opus 0.5	-	-	Twist 1.0 + Opus 0.5	-
16	Opera 0.75	-	-	Opera 0.75	-
17	Corbel 0.5	-	-	Corbel 0.5	-
18	Antioxidant	-	-	Antioxidant	-
19	Amistar 0.5 + Unix 0.4 kg	-	-	Amistar 0.5 + Unix 0.4kg	-
20	Unix 0.4kg	-	-	Unix 0.4 kg	-

Core treatments comprising Amistar applied at specific crop growth stages was maintained throughout the three years, but treatments comprising new fungicides changed as new products became available to test.

In the final year, the comparison of triazole based programmes with strobilurin based programmes was stopped. Treatments were later based upon strobilurin fungicides only but the fungicide timings were changed to determine the potential yield loss from spotting. This was achieved by applying a standard early fungicide at GS25-30 and manipulating the timing of the second treatment to ensure all treatments had identical fungicides applied, but at good and poor timings to control spots as defined by trials in the first two years of the project.

Results

Timing of fungicides

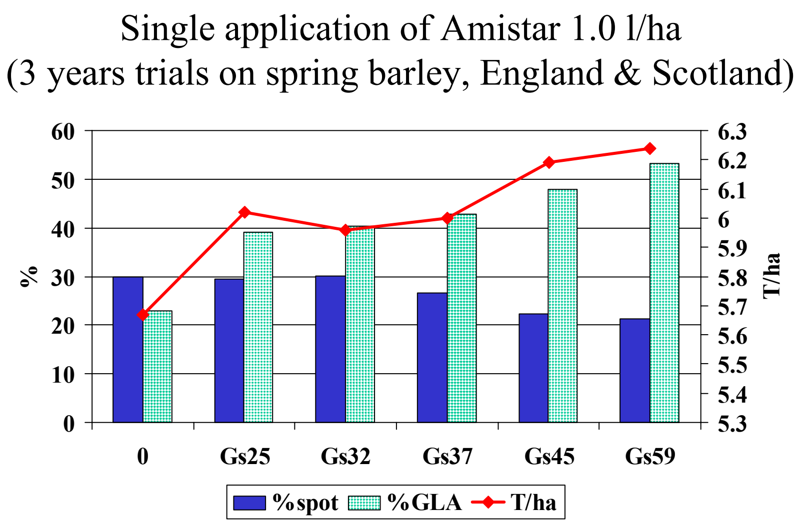
Table 4 and Figures 1 and 2 show the results from Amistar treatments applied at 1.0 l/ha at growth stages ranging from Gs25 up to Gs59 over three years trials in England and Scotland.

Table 4 Foliar assessments on leaf 2 in mid to late July.

		Yield T/ha	% Spotting leaf 2	%Green leaf area leaf 2	SPWT KG/HL	% Screenings*
1	Nil	5.67	29.9	22.9	67.0	8.2
4	Amistar 1.0 Gs25-30	6.02	29.5	39.2	67.3	7.1
5	Amistar 1.0 Gs32-33	5.96	30.2	40.4	67.3	7.5
6	Amistar 1.0 Gs37-39	6.00	26.6	42.9	67.1	6.8
7	Amistar 1.0 Gs39-45	6.19	22.4	47.9	67.6	6.7
8	Amistar 1.0 Gs59	6.24	21.2	53.2	67.9	5.8
Sed		0.061	1.81	2.98	0.17	0.42
Sig		<.001	<.001	<.001	<.001	<.001

* % screenings Edinburgh trials only

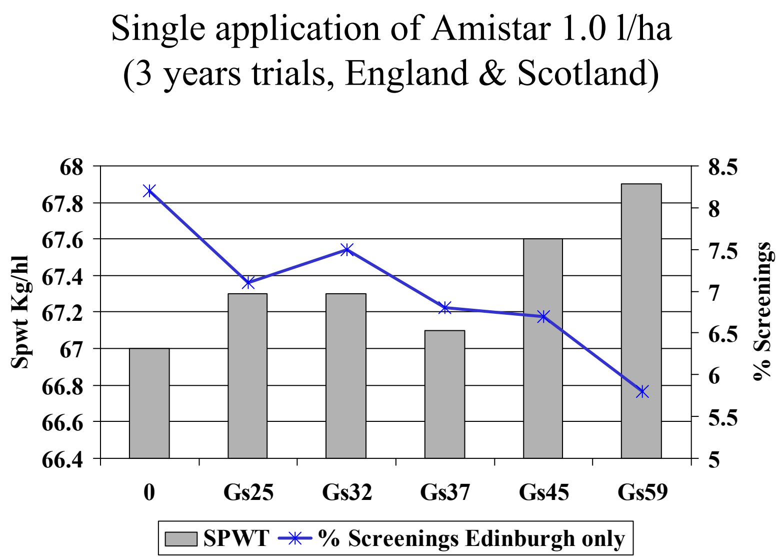
Figure 1



On the basis of these results, the best yields were achieved with the later fungicide timings of Gs45 and Gs59. The same treatments also achieved the best green leaf area retention on leaf 2 in July and saw the lowest level of spotting. Note however that no treatment achieved complete control of spotting and the untreated control did not always show the highest degree of leaf spots. One reason for this is that other diseases, in particular Rhynchosporium can kill out the green leaf resulting in no opportunity for leaf spots to develop.

The highest specific weight and lowest screenings value were seen with the GS59 timing and the lowest yield and highest screenings with the untreated, Gs32 and Gs37-39 spray timings (Figure 2)

Figure 2



Amistar applied at Gs25-30 achieved a better yield compared to a Gs32 or Gs39. The most likely reason for this is that barley spotting was only one disease present in the trials. Rhynchosporium also developed in some of the trials. A fungicide timing of Gs25-30 would provide protection from Rhynchosporium but poor control of spotting. A spray timing of Gs32 achieved poor control of both Rhynchosporium and barley spotting. The results demonstrate that achieving a single treatment to protect a susceptible variety from Rhynchosporium (early treatment) and barley spot (late treatments) is not achievable. Growers who compromise the timing of both diseases in fact compromise control of both Rhynchosporium and barley spot.

Leaf spotting developed in all trials in the three years. Table 5 indicates that levels of spots were higher in the Scotland trials compared to England. Spots in England were however higher in 2001 than in the two previous years in the same region.

Table 5 Comparison of spotting in England and Scotland

	1999		**2000**		**2001**	
	Untreated	**Treated GS45**	**Untreated**	**Treated GS45**	**Untreated**	**Treated GS45**
Scotland	23.8	7.3	58.8	82.0	37.0	19.5
England	13.0	5.1	9.3	4.0	37.5	16.8

SED	Year	1.81	Region	1.48	Fungicide	2.56
Sig		<.001		<.001		<.001

A single treatment of Amistar applied at Gs45 reduced the level of spotting except at the Edinburgh site in 2000. Using spot levels as a measure of control can however be misleading. It is normal for untreated crops to have low levels of spotting, particularly where Rhynchosporium has developed earlier and killed out the green leaf. Conversely, in late assessments, treatments which retain green leaf area for longer will develop more spots. Once a leaf is dead, spots do not develop further. Where control was achieved, the level of control of spots ranged from approximately 25% control to 70% control in these trials.

Yield responses from the single application of Amistar at Gs45 achieved a yield benefit in England and Scotland in all three years. Yield response varied from 0.2 - 0.8 T/ha. The best yield responses were seen where levels of spots were lowest. (Table 6).

Table 6 Comparison of yield in England and Scotland

	1999		**2000**		**2001**	
	Untreated	**Treated GS45**	**Untreated**	**Treated GS45**	**Untreated**	**Treated GS45**
Scotland	6.68	7.04	5.63	5.83	6.01	6.80
England	5.31	6.14	5.82	6.43	4.62	4.80
SED	0.225					

SED	Year	5.96	Region	0.050	Fungicide	0.087
Sig		<.001		<.001		<.001

Figure 3 shows spot levels and yields for the Scotland trials and Figure 4 the yields and spot levels in the England trials.

Figure 3

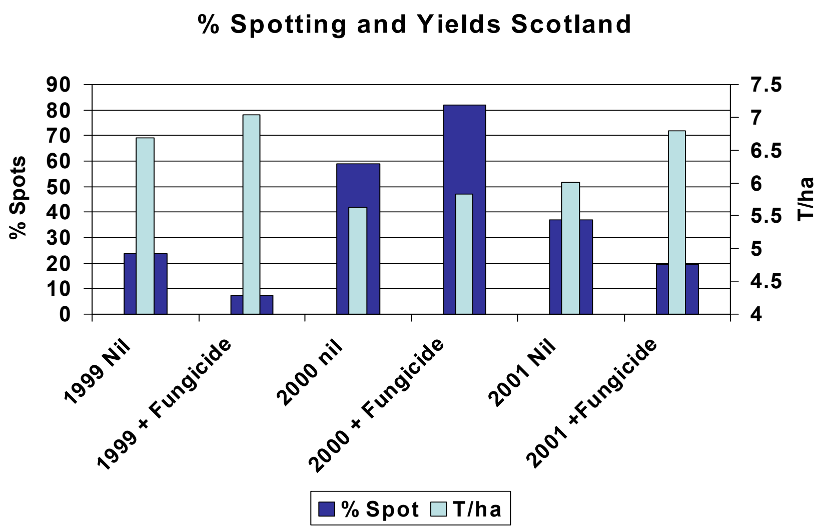
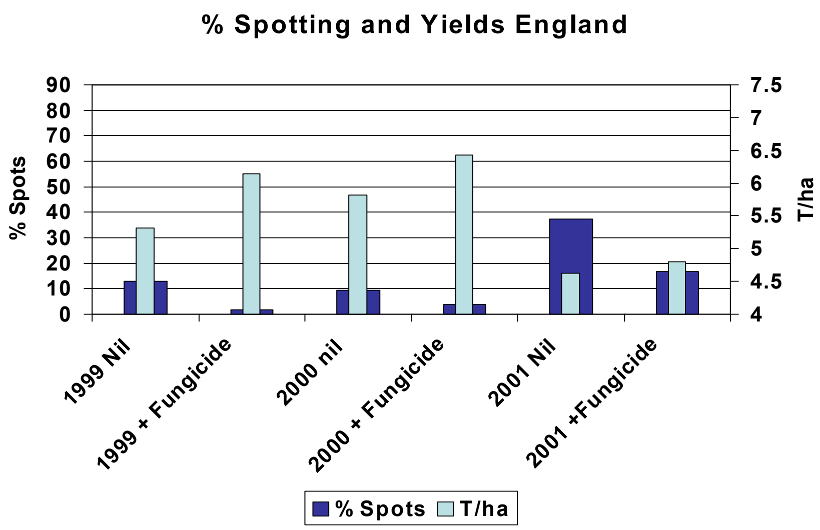


Figure 4



Progress of spots

Ramularia barley spots and abiotic spots are rarely seen in the crop until the crop reaches head emergence and starts to flower (Figure 5 below). The graph shows how the application of Amistar has reduced the severity of spots but the spots still appeared at the same crop growth stage as the untreated.

Figure 5

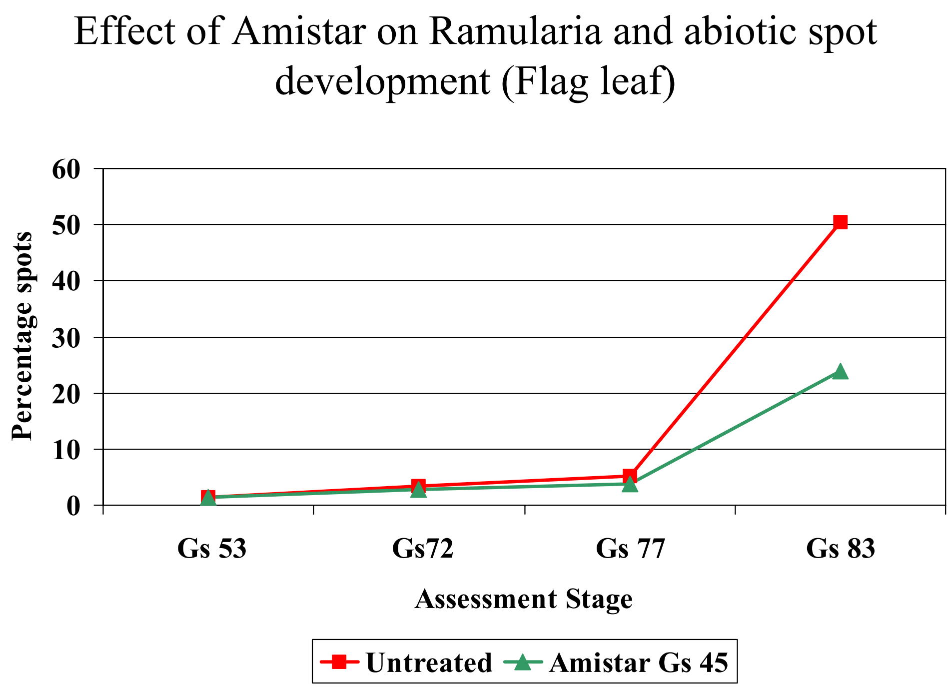
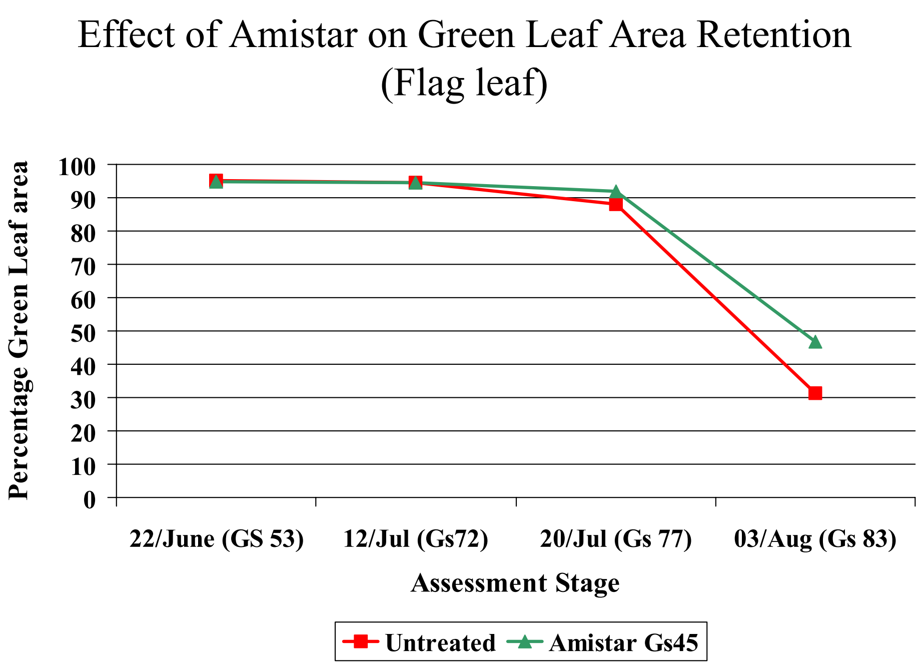


Figure 6 (below) shows the impact on green leaf area. The application of Amistar resulted in less green leaf area loss, but it did not delay the start of the decline in green leaf area

Figure 6



Ramularia and abiotic spots generally occur on the upper leaves from when the crop is starting to flower. Fungicide application to the upper leaves can reduce the severity of spots and improve green leaf area retention, but total control of spots is unlikely to occur.

Impact of spots on crop yields

Table 7 shows the treatments from a trial at Bush (Scotland) designed to determine the impact of spots on yield.

Table 7 Wave 2001 Bush

Proposed Time	GS 25-30	GS 37	GS 45	GS 59
1	Nil	Nil	Nil	Nil
2	Amistar Pro 2.0 l/ha + Unix 0.67 kg/ha	Amistar Pro 2.0 l/ha + Unix 0.67 kg/ha	-	
3	Amistar Pro 2.0 l/ha + Unix 0.67 kg/ha	-	Amistar Pro 2.0 + Unix 0.67	
4	Amistar Pro 2.0 l/ha + Unix 0.67 kg/ha	-	-	Amistar Pro 2.0 + Unix 0.67

Table 8a and Figure 7 show results of an assessment when spots were well developed on leaf 2.

Table 8a Assessment 30 June 2001 milky ripe stage

Proposed Time	% Green leaf area leaf 2	Rhynchos porium	Ramularia	Abiotic spots	All spots
1	35.0	19.0	14.5	22.5	37.0
2	57.5	0	19.8	20.8	40.5
3	81.2	0	11.3	16.3	27.5
4	90.0	0.1	0.8	10.0	10.8
SED	8.05	4.60	3.43	6.93	8.19
Sig.	<.001	<.001	<.001	Ns	<.001

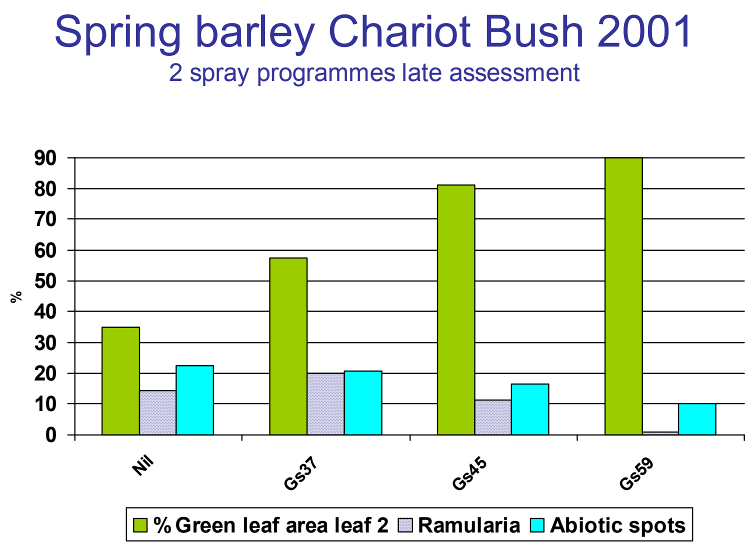


Table 8b shows the yield data from the same field trial.

Table 8b Yield and quality Assessment 2001

Proposed Time	**T/ha**	**Spwt**	**% Screenings**	**Yield difference compared to 2 (T/ha)**
1	6.01	64.5	11.4	+0.65
2	6.66	63.8	10.5	0
3	6.91	64.0	9.5	-0.25
4	6.94	63.9	9.4	-0.28
	0.154	0.469	0.82	
	<.001	0.05	0.02	

The results from this trial show how both biotic and abiotic spots developed on the crop, but green leaf area was maintained with the later spray timings. The reduction in biotic spots (*Ramularia collo cygni* and *Leptosphaeria nodorum*) has been more successful than the reduction in abiotic spots.

Correlations between spots and yield are indicated in table 8c. With 80 groups of observations, values greater than 0.3375 will be significant (regression values in bold in Table 8c). Yield correlated closer to green leaf area and to Rhynchosporium than to Ramularia spots. One reason for this is that where green leaf area is low due to Rhynchosporium, there is little leaf remaining for spots to develop. As such it is common for crops with high levels of Rhynchosporium to have low levels of spots but poor yields. There was a better correlation between abiotic spots and yield however.

Table 8c   Correlations between yield and leaf 2 assessment

	Yield	Green leaf	Rhyncho sporium	Biotic spots	Abiotic spots	% screenings 2.5 mm
Yield	1					
Green leaf area	**-0.892**	1				
Rhynchosporium	**-0.752**	**0.891**	1			
Biotic spots	-0.269	**0.490**	**0.557**	1		
Abiotic spots	**-0.564**	**0.379**	0.248	**-0.365**	1	
% Screenings	**-0.785**	**0.446**	0.278	-0.181	**0.518**	1

On the basis of this trial, the yield difference of 0.28 tonnes /ha (difference between treatment 2 and treatment 4) can be attributable to barley leaf spots in the variety Chariot.

.

Fungicide comparison

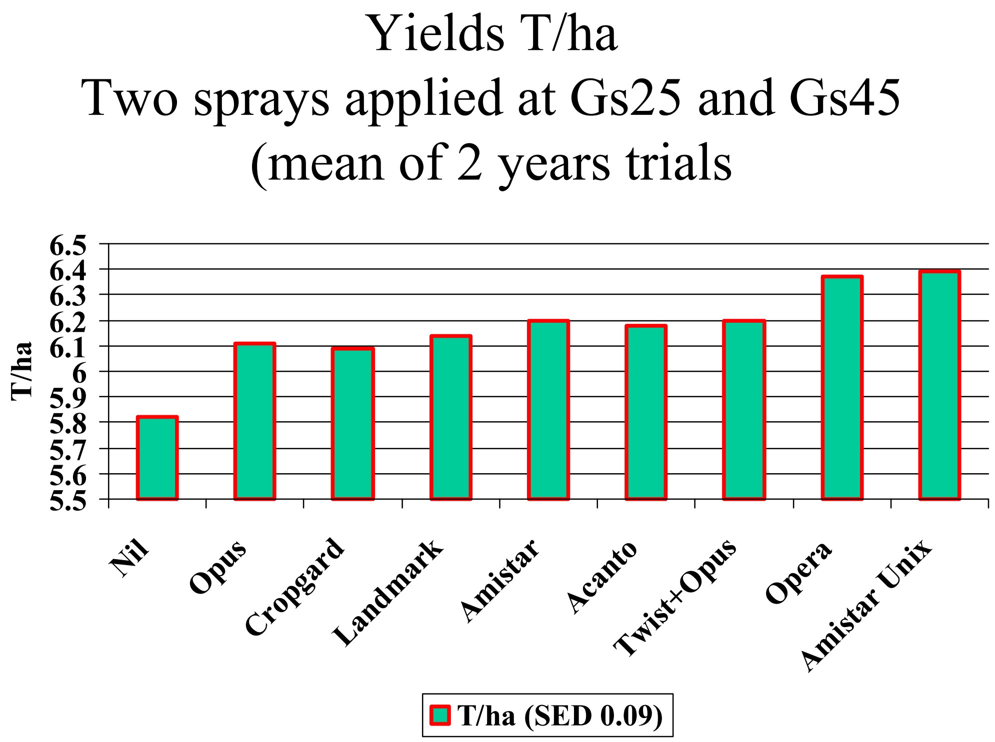
Some fungicides were tested in two seasons. The results can be seen in Table 9. The impact of these programmes on crop yield can be seen in figure 8. and on green leaf area and spot development in Figure 9.

Table 9 Results from trials in Scotland 2000 and 2001

GS25 and Gs45 treatment	**% Spots on leaf 2 in July**	**%Green leaf area on leaf 2 in July**	**Yield T/ha**	**SPWT**
Nil	**43.4**	**28.2**	**5.82**	**64.5**
Opus	**50.7**	**42.4**	**6.11**	**64.8**
CropGard	**57.8**	**37.8**	**6.09**	**64.8**
Landmark	**52.0**	**42.5**	**6.14**	**64.5**
Amistar	**50.8**	**37.4**	**6.20**	**64.9**
Acanto	**56.1**	**39.9**	**6.18**	**64.0**
Twist+Opus	**56.9**	**42.6**	**6.20**	**64.6**
Opera	**54.8**	**43.3**	**6.37**	**64.8**
Amistar Unix	**58.4**	**42.2**	**6.39**	**65.6**
	2.57	**3.36**	**0.090**	**0.228**
	<.001	**<.001**	**<.001**	**<00.1**

Realistically some of the products will not be used alone in a fungicide programme, but the results indicate that the fungicide mixtures comprising a strobilurin + triazole (in Twist + Opus or Opera) and strobilurin + cyprodinil (in Amistar + Unix) achieved the best yields.

Figure 8 Comparison of fungicides



No treatment achieved effective control of leaf spotting however. (Figure 9)

Figure 9

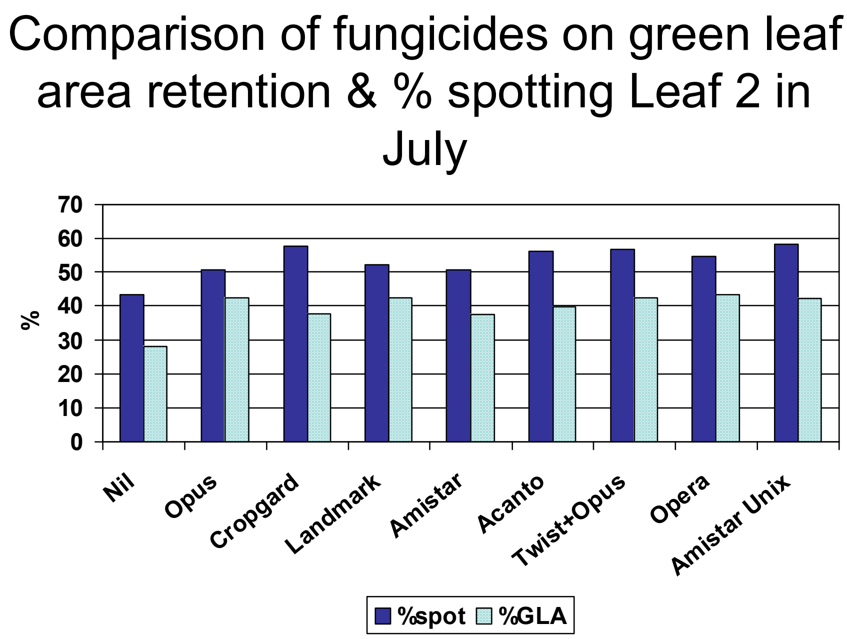


Table 10 shows data from one trial in 2001 where spots developed to a high level.

Table 10 Assessment of leaf 2 in July 2001

Fungicide	Yield T/ha	*MOFC	% Rhynchosporium	% Green leaf area	% Biotic spots	% Abiotic spots
Nil	6.01	480	19.0	35.0	14.5	22.5
Corbel 0.5	6.32	488	2.5	47.5	20.5	32.5
Unix 0.4kg	6.63	512	6.8	62.5	19.5	14.8
Mycoguard 2.0	6.51	505	1.3	72.5	1.8	25.8
Opus 0.5	6.48	498	3.8	77.5	4.3	19.3
Landmark 0.5	6.63	494	0	82.5	4.5	12.0
Opera 0.75	6.78	502	4.0	85.0	6.3	13.8
Amistar 0.5	6.57	498	2.3	73.7	10.5	18.3
Acanto 0.5	6.71	505	1.8	77.5	9.8	17.5
Twist 1.0 + Opus 0.5	6.79	493	2.0	83.7	3.8	18.8
Amistar 0.5 + Unix 0.4 kg	6.99	513	0	62.5	10.8	15.3
SED	0.155		4.60	8.05	3.43	6.93
Sig.	<.01		<.001	<.001	<.001	Ns

*MOFC - Margin over fungicide cost based on a grain price of £80/tonne

Biotic spots in 2001 were effectively controlled with Mycoguard, Twist + Opus, Landmark, Opus and Opera. Reduction in abiotic spots was less successful and differences were not significant. There was an indication of more abiotic spots in the Corbel treatment however and Landmark achieved the lowest abiotic score.

Discussion

Barley spots were worse in the north of Britain than in East Anglia. There was however a higher level of abiotic spotting in East Anglia in 2001 compared to previous seasons. Spots also appeared in all three seasons.

Barley spots can be minimised using fungicides, but they are more effective against biotic spots than abiotic spots. The optimum timing to prevent damage to the upper leaves from both types of spots is boot stage to head emergence. In practical terms, boot stage is a useful compromise since some fungicides cannot be applied to barley crops after boot stage (e.g. Unix to all barley crops and Opus to malting barley crops).

Trying to achieve control of spots earlier than flag leaf emergence is not possible. Yields were in fact lower where one fungicide was applied at 2 nodes detectable (Gs32) compared to earlier or later treatments. The reason for this is this timing is too late to control early Rhynchosporium and too early to control leaf spots.

Although Opus + strobilurin achieved the best control of spots and the best yield, spots did eventually appear in all treatments. The fungicide will delay their development and maintain green leaf area sufficiently to achieve good yields and lower levels of screenings. In 2001, the yield loss specifically from leaf spots was 0.28 tonnes/ha. This yield loss is lower than that achieved by not applying a second fungicide on spring barley, so takes account of the fact that strobilurin fungicides can improve yield in the absence of visible disease.

Trying to relate spots to yield loss is difficult since high levels of Rhynchosporium will kill out the leaves so there is less green leaf for spots to develop. Conversely spots may appear very late causing little damage to yield. The relationship between green leaf area retention on leaf two in July and yield was better than the correlation between leaf spotting and yield. Spots, which develop soon after ear emergence, are likely to be more damaging to yield and quality than spots, which develop later in the season. Unfortunately waiting until the spots appear before you treat is too late.

All you can expect from fungicides is a delay in the symptoms developing, since no fungicide mixture effectively controlled spots to harvest. The strobilurin fungicides, Opus and chlorothalonil achieved the best reduction, whilst the addition of a strobilurin fungicide achieved the best yield response. As a result of these trials, the recommended approach is to apply a fungicide at boot stage comprising strobilurin + Opus before spots appear. Chlorothalonil remains a cost effective product but the number of products approved on barley is now limited and unlikely to be increased.

Unix was less effective at controlling leaf spots, but in mixture with Amistar achieved the best yields, particularly in East Anglia where Ramularia spots were generally low.

Corbel occasionally achieved poor results and under certain conditions may lead to a greater loss in green leaf area. Corbel should therefore be avoided wherever possible if the key aim is to protect the crop from barley leaf spots at boot stage.

Section 4 Field trials investigating the different responses of varieties to barley spotting

Key authors: Karene Sutherland, Neil Havis, Simon Oxley

Materials and Methods

Six field trials were carried out in Borders, Lothians, Aberdeenshire and Kincardineshire during 1999 - 2001. A range of varieties were included in each trial, the varieties chosen because of their susceptibility to necrotic spotting (Table 1). In 1999 and 2000 the fungicide programmes were a triazole based and a strobilurin based programme (Tables 2 & 3). In 2001 all fungicide programmes were based on strobilurins (Table 4). The trials were sown as randomised blocks, plot size 40 m^2, 4 replicates. Plots were sown using an Oyjord drill. Except for fungicide treatments, trials received standard agronomic inputs for the area.

Table 1. Varieties used to determine the interaction between fungicide and varietal genetics on the development and control of necrotic spotting in spring barley, 1999 - 2001

1999	2000	2001
Prisma	Chariot	Chariot
Optic	Optic	Optic
Chariot	Decanter	Decanter
Cooper	Pewter	Pewter
Century	Berwick	Berwick
Newgrange		County
Delibes		
Henni		

Table 2. Fungicide treatments to determine the interaction between fungicide and varietal genetics on the development and control of necrotic spotting in spring barley, (1999 trials)

Proposed application growth stage	GS 30/31	GS 45-49
1	Nil	Nil
2	Punch C 0.625 l/ha+ Corbel 0.75 l/ha	Opus Team 1.5 l/ha
3	Amistar pro 2.0 l/ha + Unix 0.67 kg/ha	Amistar pro 2.0 l/ha

Table 3. Fungicide Treatments to determine the interaction between fungicide and varietal genetics on the development and control of necrotic spotting in spring barley, 2000

Proposed time	GS25-31	GS 39-45
1	Nil	Nil
2	Punch C 0.625l/ha + Corbel 0.75l/ha + Unix 0.67 kg/ha	Opus Team 1.5 l/ha
3	Amistar pro 2.0 l/ha+ Unix 0.67 kg/ha	Amistar pro 2.0 l/ha
4	Amistar pro 1.0 l/ha+ Unix 0.35kg/ha	Amistar pro 1.0 l/ha

Table 4. Fungicide Treatments to determine the interaction between fungicide and varietal genetics on the development and control of necrotic spotting in spring barley, 2001

Proposed time	GS 25-31	GS 33-37	GS 39-45
1	Amistar 0.8l/ha + Unix 0.67 kg/ha	-	-
2	Amistar 0.8l/ha + Unix 0.67 kg/ha	Amistar 0.8l/ha + Unix 0.67 kg/ha	-
3	Amistar 0.8l/ha + Unix 0.67 kg/ha	-	Amistar 0.8l/ha + Unix 0.67 kg/ha
4	Amistar 0.8l/ha + Unix 0.67 kg/ha	-	Amistar 0.8l/ha + Unix 0.67 kg/ha + Corbel 0.5 l/ha

Assessment of recommended Lists Trials

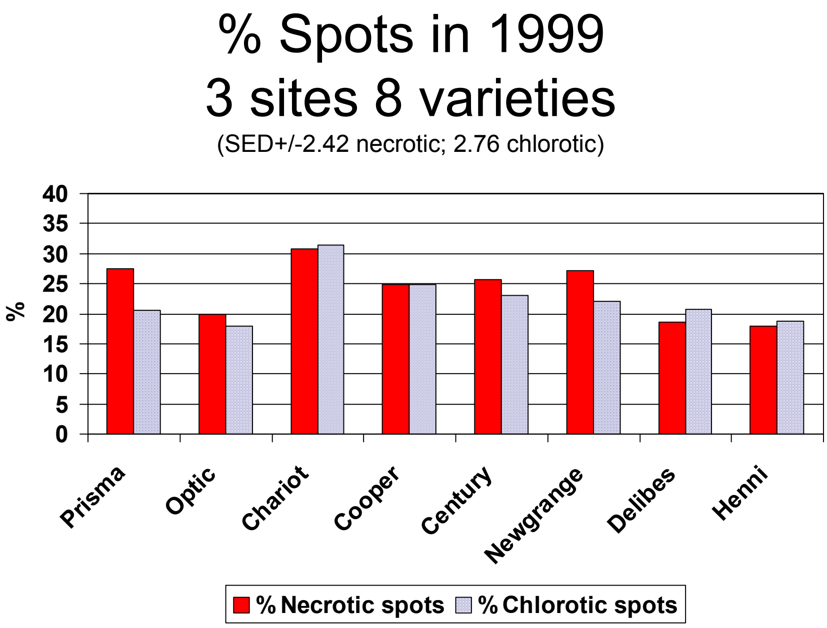
In 1999 and 2001, two recommended list trials based in Scotland were assessed in July for leaf spotting and green leaf area. The results were used to determine the susceptibility of a range of currently recommended varieties to barley spotting.

Results

Variety Trials 1999

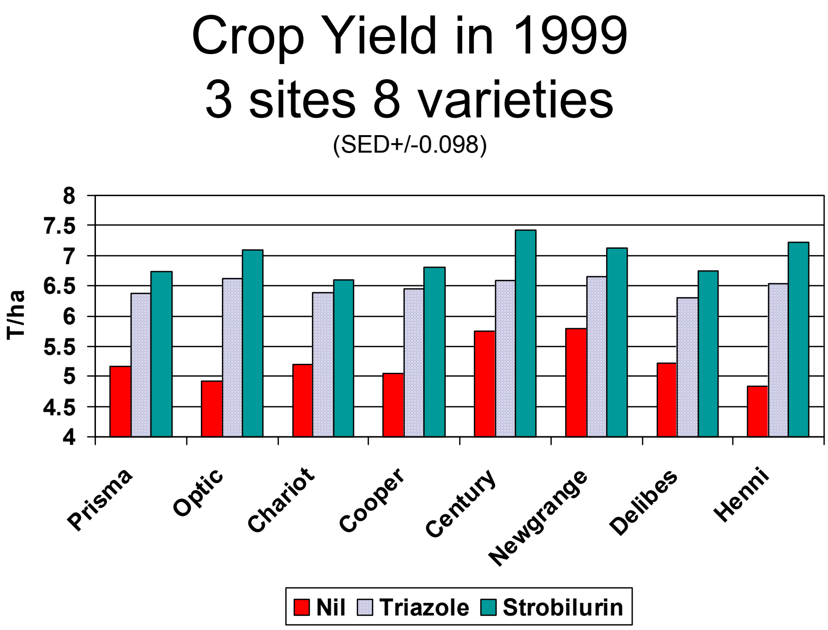
In the first season of the project, our experience at differentiating different types of spots was limited. Figure 1 shows the % of necrotic and chlorotic spots on leaf 2 in July. Note of the varieties tested, Chariot was affected most, but all varieties showed spotting symptoms. (Data mean of three spray programmes and three sites)

Figure 1



When comparing the yields, Chariot (the variety with most spots) achieved the lowest yields in all fungicide programmes. Note that in all cases the strobilurin programme achieved better yields than a triazole based fungicide programmes (Figure 2).

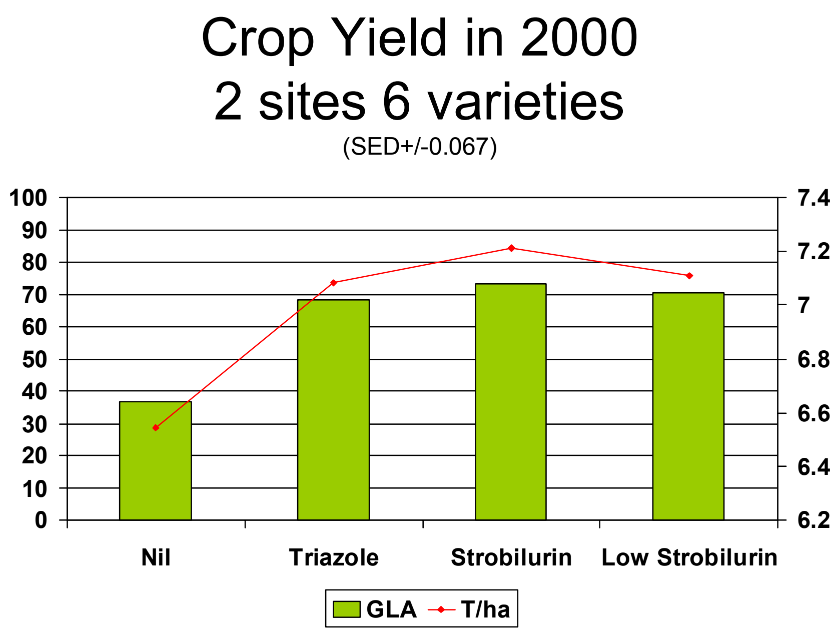
Figure 2



Variety Trials 2000

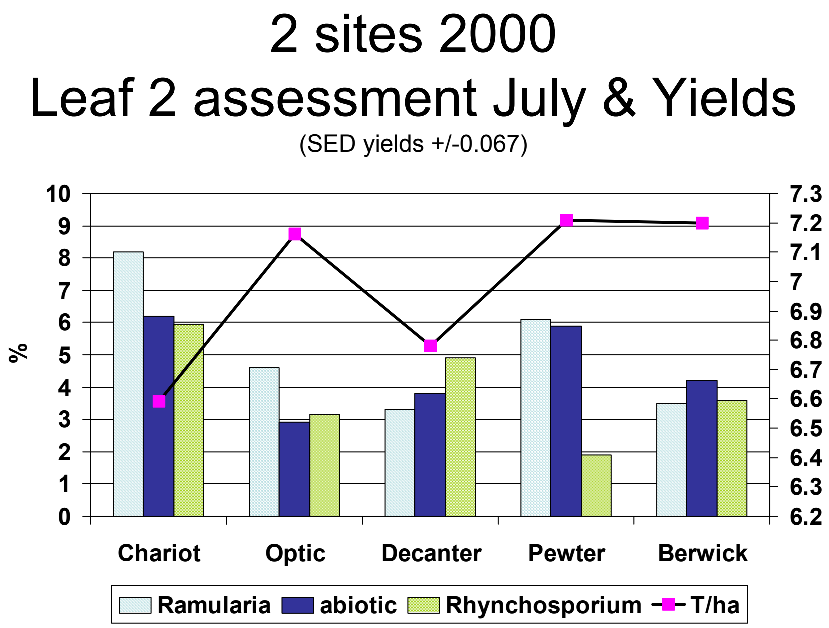
A programme based on strobilurin fungicides achieved the best yield and the best green leaf area retention on leaf two in July . Cutting the dose of the strobilurin programme achieved a lower yield equivalent to the triazole based programme. (Figure 3)

Figure 3



The level of spots was higher in Chariot and Pewter than in Optic, Decanter and Berwick. In the case of Chariot, this resulted in the lowest yield of the varieties, but Pewter achieved some of the better yields. The results suggest that lower yields were achieved where Rhynchosporium levels were highest, followed by abiotic spots and biotic spots. (Figure 4)

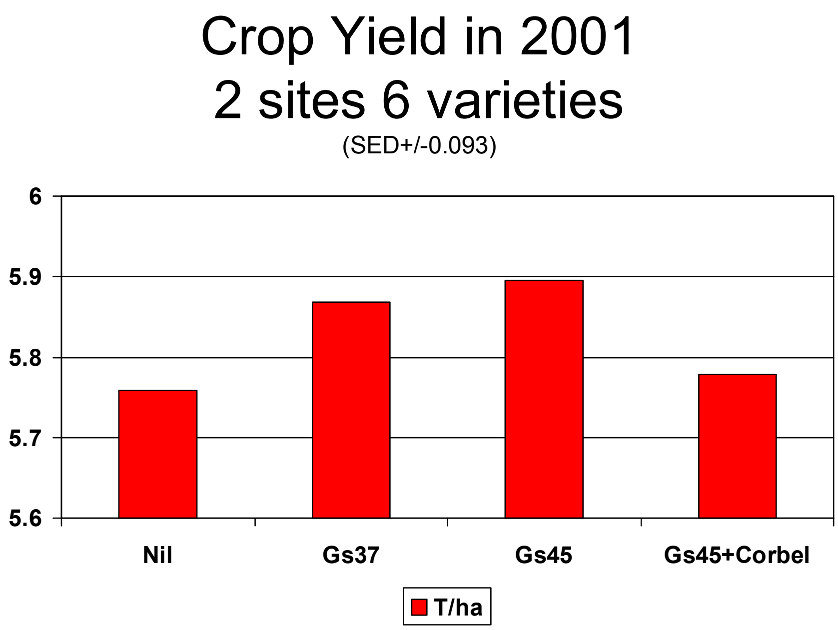
Figure 4



Variety trial 2 sites in 2001

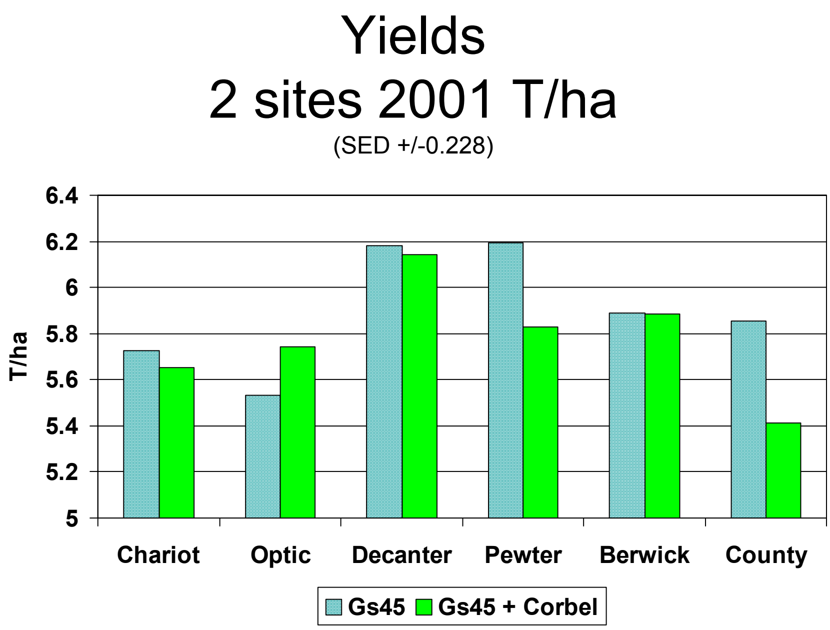
In 2001, all treatments were treated with an early standard fungicide The fungicides applied later were applied at different growth stages. The best yield was obtained where the second fungicide was applied atGs45 (boot stage). Treating the crop earlier at flag leaf emergence gave a similar yield, but the addition of corbel gave an overall yield reduction.(Figure 5)

Figure 5



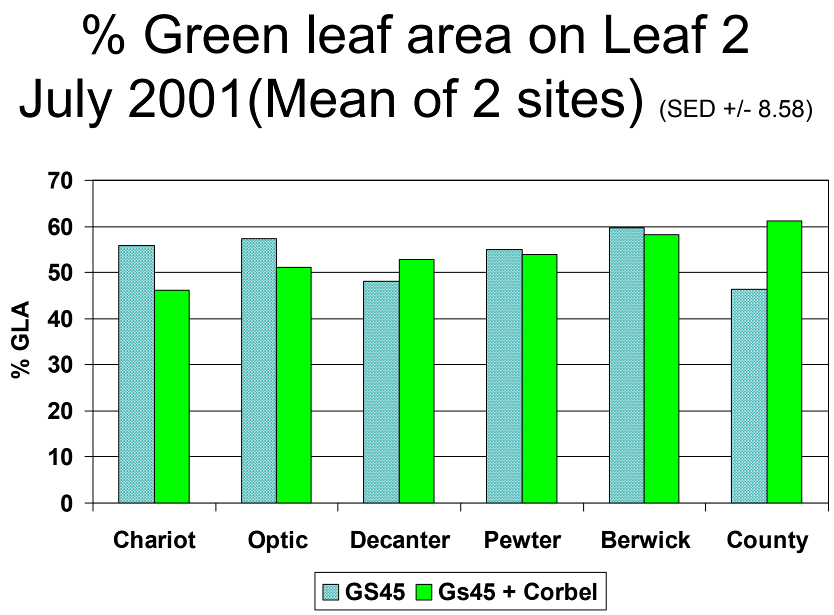
The effect of the corbel on reducing yield was most obvious in Pewter and County. In Optic, the addition of Corbel in fact resulted in a better yield. This may be a reflection of the susceptibility of Optic to both mildew and Rhynchosporium (two diseases corbel will help reduce). (Figure 6)

Figure 6



Despite the reduction in yield from the addition of Corbel in County, this treatment actually benefited the green leaf area retention in the variety. Note in Chariot and Optic, Corbel did reduce the green leaf area retention (Figure 7)

Figure 7



Recommended List Trial results

In 1999, two Recommended list trials were assessed for biotic spots late in the season. Table 5 shows the average score for leaf spotting on leaf two from the untreated plots.

Two trials were assessed in 2001 for biotic spots (including Ramularia), abiotic spots and green leaf area retention. The results in Table 6 indicate the average results for treated and untreated plots. Subjective scores for resistance to biotic leaf spots, abiotic leaf spots and green leaf area retention are also present in the table, based on a 1-9 scale where 1 = Leaf 2 very susceptible to spots in July and 9 shows good resistance to spots on leaf 2 in July.

The 1-9 scale for green leaf area can be defined as : 1= poor green leaf area retention on leaf 2 in July up to 9= good green leaf area retention on leaf 2 in July.

The green leaf area score is biased towards later varieties, since later varieties will retain green leaf area for longer in the season. This score may however help determine the potential impact leaf spots have on green leaf area.

Table 5 Assessment of recommended lists trials in 1999

	% Biotic spots on leaf 2 (untreated plots)	Subjective 1-9 score for biotic spots
Adonis	*	*
Cellar	*	*
Chalice	40	3
Chariot	44	3
Chime	35	3
County	*	*
Decanter	27	5
Harriot	*	*
Optic	31	6
Pewter	*	*
Prisma	31	6
Riviera	32	3
Saloon	30	5
Spike	*	*
Spire	*	*
Static	*	*
Tavern	*	*

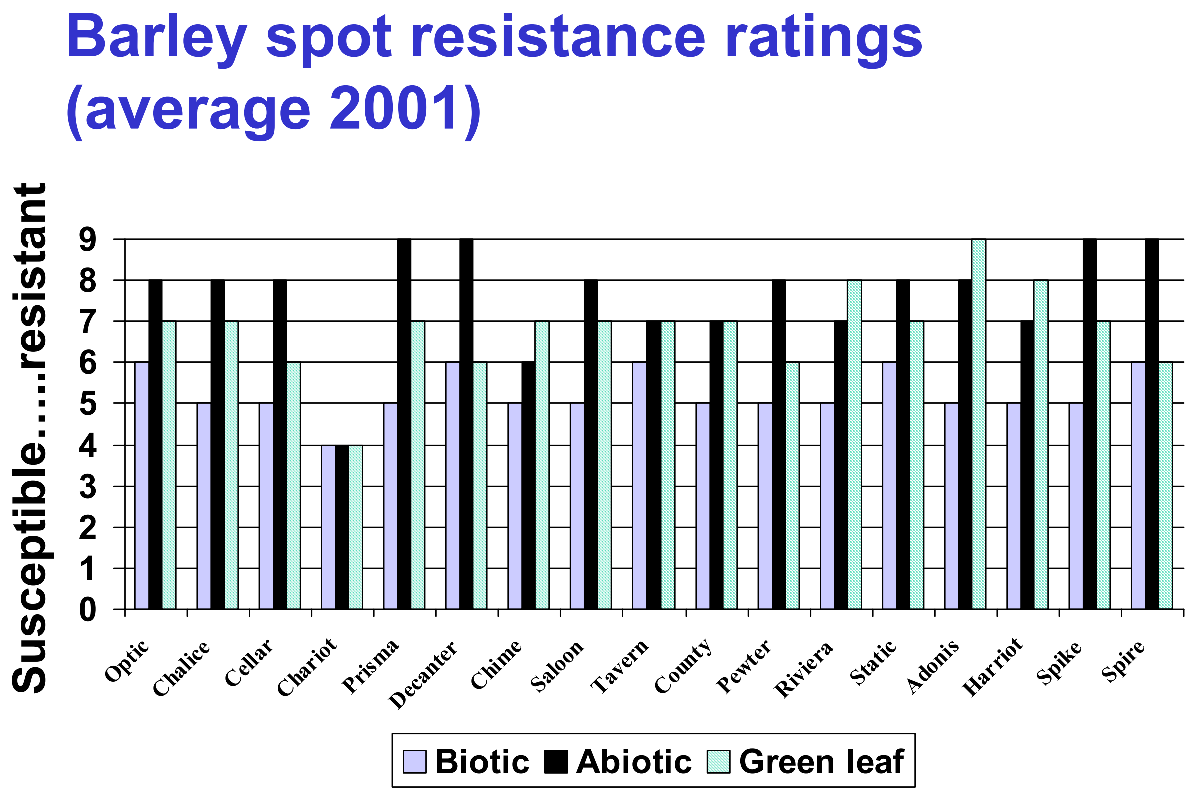
* Variety not assessed in this season

Table 6 Assessment of recommended lists trials in 2001

	% Green leaf area on leaf 2 in July	Subjective 1-9 score for green leaf area retention	% Biotic spots leaf 2 in July	Subjective 1-9 score for biotic spots	% abiotic spots leaf 2 in July	Subjective 1-9 score for abiotic spots
Adonis	73	9	10	5	1	8
Cellar	46.5	6	8.5	5	3	8
Chalice	51.5	7	9.5	5	1	8
Chariot	23.5	4	15	4	34	4
Chime	51	7	7.5	5	11	6
County	54	7	11	5	6	7
Decanter	48.5	6	5	6	0	9
Harriot	64.5	8	8.5	5	7	7
Optic	54.5	7	6	6	3	8
Pewter	48.5	6	8	5	1	8
Prisma	53.5	7	7.5	5	0	9
Riviera	67.5	8	9.5	5	6	7
Saloon	51.5	7	10	5	3	8
Spike	58	7	7	5	0	9
Spire	40	6	5.5	6	0	9
Static	52	7	5.5	6	2	8
Tavern	52	7	6.5	6	6	7

Results for the 2001 data are also detailed in figure 8.

Figure 8



The results indicate that Chariot is currently the weakest variety with resistance to both biotic and abiotic spots. It also loses green leaf area as a result of leaf spots. No variety in the current list shows effective resistance against biotic spots, but some currently show effective resistance against the abiotic leaf spotting (e.g. Prisma, Decanter, Spike and Spire).

Discussion

Results from this work indicate that different varieties exhibit different types of spots. The type of spotting that develops is dependent on variety and more than one type of spotting can occur simultaneously. Appendix 1, plates 17-26 shows a range of spots associated with varieties.

Because of the various types of spots which developed on the leaves of spring barley varieties it is difficult to attribute yield losses to any particular type of spot. One important aspect is that if a disease such as Rhynchosporium is present it must be controlled with a suitable fungicide programme as soon as possible. In varieties such as Chariot and Optic it is no use applying a fungicide to control leaf spotting if most of the yield has already been lost through earlier infections of Rhynchosporium.

In general the application of a fungicide reduced Ramularia and abiotic spotting. The green leaf area was also related to the amount of leaf affected by foliar diseases and all types of necrotic spotting. Application of a fungicide improved green leaf retention without specifically controlling any one particular type of spotting.

Within individual varieties, a significant improvement in green leaf retention at the end of the season was usually, but not always, associated with an increase in yield. The strobilurin programmes generally yielded higher than non strobilurin programmes and higher doses of strobilurins achieved better yield increases than low dose propgrammes. The addition of fenpropimorph at Gs45 had a detrimental effect on green leaf area and yield in some varieties. As such its use at this time is best avoided unless it is esential for control of established mildew or Rhynchosporium.

Varieties in recommended list trials exhibited different levels of biotic spots, abiotic spots and green leaf area retention. Differences between varieties were more obvious in abiotic spotting than in biotic/ Ramularia spotting. Green leaf area retention was greats in later varieties, so this score must be read in context to the lateness of a variety and the susceptibility of the variety to biotic and abiotic spots. None of the current varieties recommended in the UK demonstrate achieved effective resistance to spots, so all varieties in regions of the UK where spots develop will benefit from fungicide treatment at boot stage to minimise losses in yield and quality.

References

Anon (1991) Ramularia collo-cygni. *Mycologia* **114**, 61 – 62

Browne, P. (1998) Crops. *Irish Farmers' Journal*, July 4, 1998

Doyle, A. (1998a) In the fields. *Irish Farmers'Journal*, pp15 – 16, July 4, 1998

Doyle, A. (1998b) In the fields. *Irish Farmers'Journal*, pp20, July 11, 1998

Huss, H. (1999) Personal communication

Obst, A. (1999) Personal communication

Sachs, E. (1999) Personal communication

Sachs, E,, Amelung, D. and Klappach, K. (1998) Die symptome der netzfleckenkranheit der gerste, hervogerfunen durch *Dreschlera teres (Sacc.) Shoem., und deren verwechslungsoglichkeiten. Nachrichtenbl*. Deut. Pflanzenschutzd. **50**, 58 – 63

Salamati, S. (1999) Personal communication

Sutherland, K.G (1989) Necrotic spotting on barley leaves associated with *Erysiphe graminis* infection and other factors. *PhD Thesis*, Edinburgh University.

Appendix 1. KEY TO NECROTIC LESIONS IN SPRING BARLEY

DESCRIPTION OF LESIONS

- **1 Rhynchosporium** - greyish-green water soaked lesions, which eventually turn into the typical 'diamond shaped' dark brown lesions with pale centres. Lesions, up to 1 cm in length can be found in the centre or on the margins of leaves.

- **2, 3 Net Blotch** - typical symptoms are brown net-like patterns on leaves. With age, adjoining tissue becomes chlorotic. The net-like patterns initially start as brown spots which enlarge to give the net pattern but in some cases symptoms remain as spots - the spot form of net blotch.

- **4 Powdery Mildew** - symptoms are typically white, powdery spots of fungal mycelium. With time, tissue below lesions becomes chlorotic. In old lesions, where the mycelium turns fawn in colour, underlying tissue becomes chlorotic and eventually turns brown.

- **5 Septoria** (Lepthosphaeria)- brown, round to oval lesions surrounded by a yellow halo. Pycnidia may be seen in the centres of lesions. Lesions may elongate to give linear lesions between veins (*S. avenae*) or remain as spots (*S. nodorum*).

- **6 Ramularia** - clusters of small spots (1 mm diam.) between the veins, nut brown later becoming dark brown, surrounding by a chlorotic halo. Examination of affected leaves (particularly under-side) with a hand lens shows clusters of white conidia, often in lines within the lesions.

- **7, 8 Target Spotting** - sometimes known as Midas Spot. Large (1 cm diam), brown, circular lesions within which are 1-several dark brown concentric rings (targets). In severe cases the lesions merge to give extensive necrotic areas on leaves.

- **9 Manganese Deficiency** - typically plants turn pale green and leaves become floppy. Under severe deficiency lines of small brown flecks or spots appear on leaves, running between the veins.

- **10 Magnesium deficiency** - first becomes apparent as pale green beading within leaves. Under severe deficiency leaf margins show necrotic lesions with pale centres. Symptoms can be confused with Rhynchosporium lesions.

- **11, 12 Physiological stress flecking/spotting** - symptoms range from small brown flecks or spots (<1 mm) to large brown lesions (5 mm). No obvious pathogens or deficiency can be associated with these symptoms.

- **13 Chariot Spot** – lines/groups of rusty brown 'dashes' between the veins, groups amalgamating to cover large areas of the central portion of the upper leaf surface. Underlying tissue turns yellow.
- **14**. ***Ramularia collo cygni*** symptoms developing on a green leaf and on a necrotic leaf

- **15**. **Leaf segments on Agar** to culture *Ramularia collo cygni*. (Red colouration indicative of the presence of *Ramularia collo cygni*).

- **16 *Ramularia collo cygni*** Close up of on leaf tissue.

Appendix 1. KEY TO NECROTIC LESIONS IN SPRING BARLEY

DESCRIPTION OF LESIONS

- **17 Berwick** leaf spots. Typical early in season.
- **18 Cooper** leaf spots late in season.
- **19 Chariot** Early development of leaf spots.
- **20 Century** brown oval leaf spots.
- **21 Crusader** brown leaf spots.
- **22 Landlord** small leaf flecks.
- **23 Newgrange** typical leaf flecks.
- **24 Optic** small spots (with Rhynchosporium).
- **25 Pewter** extensive spots (mostly *Ramularia collo cygni* with some abiotic spots).
- **26 Riviera** small brown spots.
- **27 Growth room experiment** with plants under shades.
- **28 Growth room experiment** showing lights above shaded and unshaded plants
- **29 Unshaded plants** with spots well developed.
- **30 Shaded plants** with no spots developed.

Appendix 1. KEY TO NECROTIC LESIONS IN SPRING BARLEY

NECROTIC LESIONS DUE TO PATHOGENS

Plate 1. Rhynchosporium

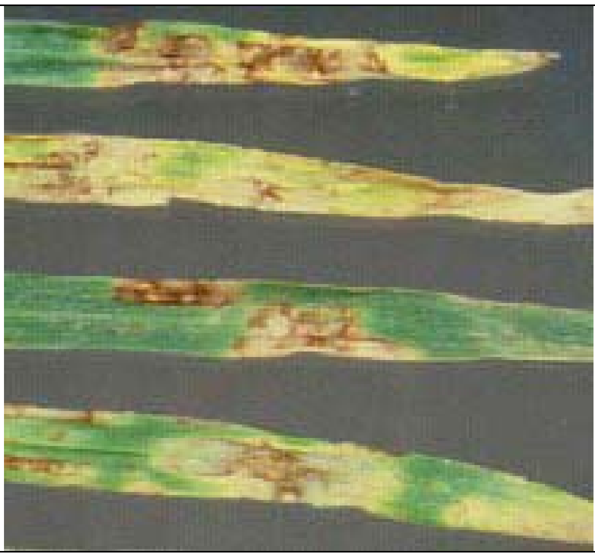


Plate 2. Net Blotch with typical net-like lesions

Plate 3. Net Blotch - spot form

Plate 4. Powdery Mildew - old lesions

Plate 5. Leptosphaeria nodorum (Septoria)

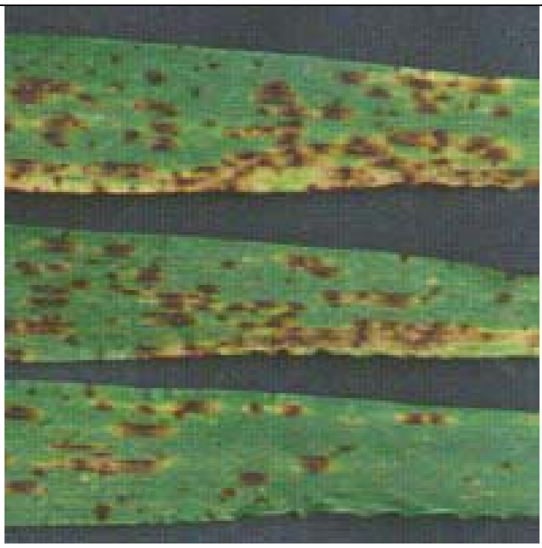


Plate 6. Ramularia collo cygni

Appendix 1. KEY TO NECROTIC LESIONS IN SPRING BARLEY

NECROTIC LESIONS DUE TO NON-PATHOGENIC DISORDERS

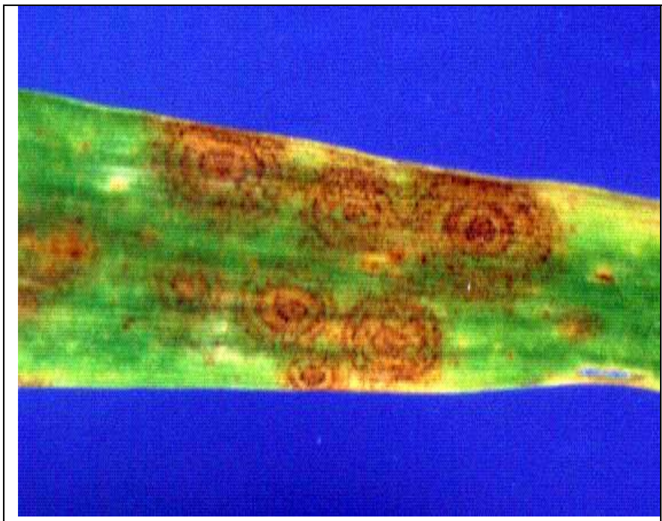


Plate 7. Target Spotting

Plate 8. Severe Target Spotting

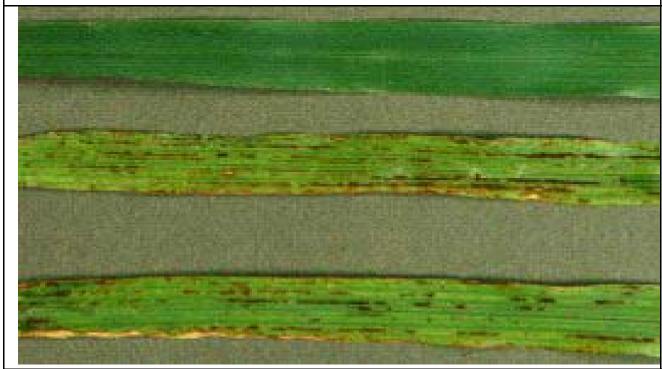


Plate 9. Manganese deficiency

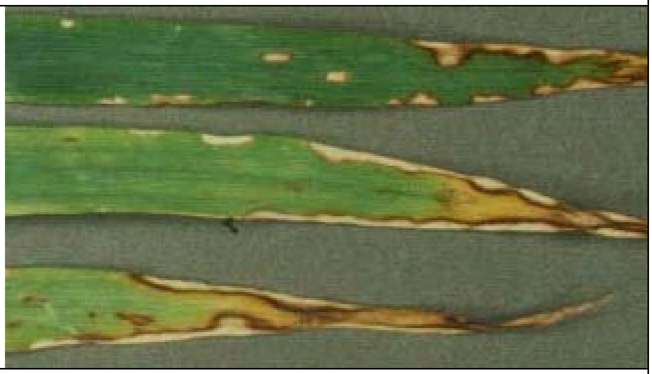


Plate 10. Magnesium deficiency

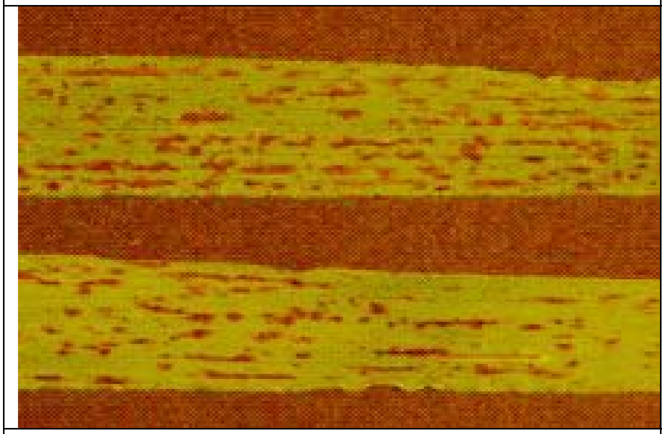


Plate 11. Physiological Stress Flecking

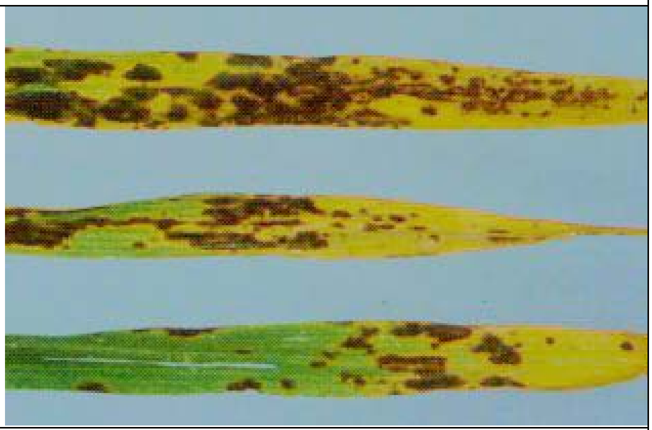


Plate 12. Physiological Stress Spotting

Appendix 1. KEY TO NECROTIC LESIONS IN SPRING BARLEY

ABIOTIC AND BIOTIC NECROTIC LESIONS

Plate 13a. Abiotic spots on Chariot

Plate 13b Abiotic spots on Chariot

Plate 14a. Biotic spots (*Ramularia collo-cygni*) on green leaf

Plate 14b. Biotic spots (*Ramularia collo-cygni)* on necrotic leaf

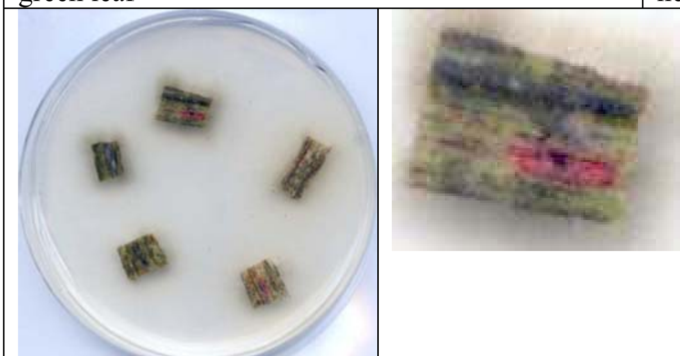


Plate 15. Ramularia on Agar (note red colouration)

Plate 16. Close up of Ramularia fungus on leaf

Appendix 1. KEY TO NECROTIC LESIONS IN SPRING BARLEY

NECROTIC LESIONS ON VARIETIES

Plate 17. Berwick

Plate 18. Cooper

Plate 19. Chariot

Plate 20.Century

Plate 21. Crusader

Plate 22. Landlord

Appendix 1. KEY TO NECROTIC LESIONS IN SPRING BARLEY

NECROTIC LESIONS ON VARIETIES

	
Plate 23. Newgrange	Plate 24 Optic
	
Plate 25. Pewter	Plate 26. Riviera

Appendix 1. KEY TO NECROTIC LESIONS IN SPRING BARLEY

SHADING EXPERIMENTS

Plate 27. Shading in growth room

Plate 28. Plants under lights in growth room

Plate 29. Physiological spots unshaded

Plate 30.Shaded leaves with no spots

Appendix 2 for Section 2

Glasshouse Experiment III – Summary Tables
Percentage Leaf Area with necrotic lesions

Optic – Flag leaf

Treatment	16/Feb/01	23/Feb/01	02/Mar/01	09/Mar/01	16/Mar/01
Untreated	3.67	7.33	6.67	10.67	10.00
Single shading	0.00	0.00	0.67	2.00	4.67
Double shading	0.00	0.00	0.33	0.67	2.67
NuFilm P	0.00	1.33	4.00	9.00	9.33
Zeneca sunscreen	2.00	3.00	4.67	6.33	12.67
Amistar	0.00	5.00	8.00	7.33	8.67
Weekly ∝-tocopherol	0.00	0.67	3.00	7.33	2.33
Single ∝-tocopherol	0.33	0.67	2.67	4.00	7.00
Higher light	2.33	3.67	10.00	12.33	11.00
Single shading-high light	0.00	0.00	0.00	0.00	1.00
Double shading-high light	0.00	0.00	1.33	1.33	3.67
SED	1.27	2.62	2.63	3.11	4.59
Significance level	Not sig.	Not sig.	P < 0.05	P = 0.05	Not sig.

Optic – F-1 leaf layer

Treatment	16/Feb/01	23/Feb/01	02/Mar/01	09/Mar/01	16/Mar/01
Untreated	11.33	10.33	10.33	14.67	12.00
Single shading	0.00	1.67	2.67	6.00	4.67
Double shading	0.00	0.00	0.67	4.67	6.67
NuFilm P	5.33	5.67	9.67	12.67	14.67
Zeneca sunscreen	6.33	8.67	10.00	11.33	17.67
Amistar	6.00	10.00	12.33	11.67	12.33
Weekly ∝-tocopherol	1.67	3.33	5.67	8.67	8.67
Single ∝-tocopherol	1.00	2.33	5.33	7.00	8.67
Higher light	5.00	5.00	21.00	20.33	15.33
Single shading-high light	0.00	0.00	1.00	1.67	4.50
Double shading-high light	0.00	0.00	3.00	4.67	9.67
SED	3.09	2.71	2.92	3.21	5.68
Significance level	P < 0.05	P < 0.005	P < 0.001	P < 0.001	Not sig.

Optic – F-2 layer

Treatment	16/Feb/01	23/Feb/01	02/Mar/01	09/Mar/01	16/Mar/01
Untreated	15.33	18.33	12.33	20.00	17.33
Single shading	1.67	3.33	5.67	7.00	7.00
Double shading	0.00	1.00	1.33	5.33	7.00
NuFilm P	6.67	12.67	13.33	13.67	15.33
Zeneca sunscreen	18.33	16.67	14.33	16.00	21.00
Amistar	11.33	14.67	12.67	14.00	12.00
Weekly ∝-tocopherol	4.33	3.67	4.33	11.67	9.33
Single ∝-tocopherol	7.33	6.33	7.33	10.00	10.67
Higher light	13.00	10.00	21.67	20.67	16.67
Single shading-high light	0.00	2.00	0.67	4.67	7.00
Double shading-high light	0.33	0.67	2.67	5.00	8.67
SED	4.67	3.87	2.60	2.78	4.24
Significance level	$P < 0.01$	$P < 0.001$	$P < 0.001$	$P < 0.001$	$P < 0.05$

Optic – F-3 layer

Treatment	16/Feb/01	23/Feb/01	02/Mar/01	09/Mar/01	16/Mar/01
Untreated	19.33	13.67	11.33	26.67	16.67
Single shading	4.00	3.33	5.67	7.00	7.67
Double shading	3.00	2.67	1.67	6.00	6.67
NuFilm P	16.67	17.00	16.00	21.67	20.33
Zeneca sunscreen	19.33	23.00	18.33	21.00	23.00
Amistar	14.33	18.33	15.33	16.67	18.33
Weekly ∝-tocopherol	6.00	7.00	7.67	11.33	10.33
Single ∝-tocopherol	10.33	6.33	8.33	8.33	9.33
Higher light	25.00	12.33	22.67	22.33	19.00
Single shading-high light	3.33	3.00	3.00	8.00	9.00
Double shading-high light	1.67	1.00	4.00	6.67	7.67
SED	3.93	4.01	3.13	4.18	3.68
Significance level	$P < 0.001$	$P < 0.001$	$P < 0.001$	$P < 0.001$	$P < 0.001$

Chariot – Flag leaf

Treatment	16/Feb/01	23/Feb/01	02/Mar/01	09/Mar/01	16/Mar/01
Untreated	0.33	1.33	2.33	5.33	5.33
Single shading	0.00	0.00	0.67	1.33	4.33
Double shading	0.00	0.00	0.00	0.33	0.00
NuFilm P	0.00	0.00	1.33	5.33	3.67
Zeneca sunscreen	0.00	0.00	1.00	3.67	5.50
Amistar	0.00	2.33	2.67	3.67	4.67
Weekly ∝-tocopherol	0.00	0.00	2.67	3.33	2.67
Single ∝-tocopherol	0.00	0.00	1.00	0.67	1.00
Higher light	0.67	0.67	3.00	1.33	1.67
Single shading-high light	0.00	0.00	0.00	0.00	2.00
Double shading-high light	0.00	0.00	2.33	0.00	1.33
SED	0.33	0.43	1.67	2.28	2.16
Significance level	Not sig.	Not sig.	Not sig.	Not sig.	Not sig.

Chariot – F-1 leaf layer

Treatment	16/Feb/01	23/Feb/01	02/Mar/01	09/Mar/01	16/Mar/01
Untreated	3.67	3.67	4.00	8.33	6.00
Single shading	0.00	0.00	3.67	4.67	7.33
Double shading	0.00	0.00	0.67	1.67	3.33
NuFilm P	3.00	3.67	7.00	10.33	9.67
Zeneca sunscreen	1.33	2.67	3.67	5.00	8.50
Amistar	3.33	3.00	5.67	9.33	7.00
Weekly ∝-tocopherol	2.00	3.33	7.33	7.67	5.67
Single ∝-tocopherol	2.33	2.00	5.67	5.00	5.67
Higher light	2.00	2.00	4.67	5.67	3.33
Single shading-high light	0.00	0.33	1.00	2.33	6.33
Double shading-high light	0.00	1.33	6.00	2.67	3.33
SED	0.99	1.30	1.93	2.96	2.51
Significance level	P < 0.005	P < 0.05	P < 0.05	Not sig.	Not sig.

Chariot – F-2 layer

Treatment	16/Feb/01	23/Feb/01	02/Mar/01	09/Mar/01	16/Mar/01
Untreated	4.67	6.00	9.00	11.67	8.67
Single shading	2.33	3.00	7.00	7.33	8.67
Double shading	0.00	0.67	1.00	3.33	7.00
NuFilm P	5.00	4.67	7.00	9.33	11.67
Zeneca sunscreen	4.33	4.00	6.00	10.67	10.00
Amistar	4.00	4.67	9.33	11.00	10.67
Weekly ∝-tocopherol	4.67	5.33	12.00	10.00	7.67
Single ∝-tocopherol	6.33	3.33	9.00	10.00	12.33
Higher light	3.67	4.33	6.33	7.33	6.67
Single shading-high light	1.67	0.00	6.00	6.00	7.00
Double shading-high light	0.00	0.33	4.67	7.33	4.33
SED	1.60	1.48	2.31	2.54	2.07
Significance level	P < 0.01	P < 0.005	P < 0.05	Not sig.	P < 0.05

Chariot – F-3 layer

Treatment	16/Feb/01	23/Feb/01	02/Mar/01	09/Mar/01	16/Mar/01
Untreated	5.00	8.67	10.33	12.33	9.67
Single shading	3.67	3.00	7.33	8.33	9.67
Double shading	1.00	1.67	1.33	4.67	8.00
NuFilm P	5.67	9.33	8.67	12.67	13.67
Zeneca sunscreen	5.33	5.67	7.00	10.67	12.00
Amistar	4.67	9.33	9.67	11.33	10.00
Weekly ∝-tocopherol	4.33	9.00	13.00	9.33	9.33
Single ∝-tocopherol	6.33	5.33	10.00	10.67	11.33
Higher light	4.00	5.67	6.67	8.67	8.00
Single shading-high light	1.67	0.33	10.67	8.67	7.00
Double shading-high light	1.00	1.33	4.67	7.67	7.00
SED	1.54	2.41	2.72	2.23	1.88
Significance level	P < 0.05	P < 0.005	P < 0.05	Not sig.	P < 0.05

Shading Experiment - Field Trial Results

Assessment One Gs 42

Treatment	Rhynchosporium	Chlorosis	Necrosis
A (shaded)	1.33	8	3.67
U (shaded)	1.25	6.67	3.33
B (shaded)	1.89	5.67	6.67
A (unshaded)	0.22	5.33	4
U (unshaded)	4.0	6	5
B (unshaded)	1.89	7	7.33
SED	**1.05**	**0.67**	**1.02**

Assessment Two Gs 62

Treatment	Rhynchosporium	Chlorosis	Necrosis
A (shaded)	0.33	6.33	3.0
U (shaded)	2.11	6.33	4.33
B (shaded)	7.89	18.0	11.33
A (unshaded)	1.67	5.0	6.0
U (unshaded)	2.0	5.67	8.0
B (unshaded)	6.11	10.33	10.33
SED	**2.70**	**2.19**	**0.75**

Assessment Three Gs 72

Treatment	Rhynchosporium	Chlorosis	Necrosis
A (shaded)	8.54	4.67	1.67
U (shaded)	10.0	6.67	3.33
B (shaded)	18.0	8.33	7.0
A (unshaded)	7.55	5.33	15.0
U (unshaded)	21.88	14.0	18.67
B (unshaded)	24.55	10.0	13.0
SED	**9.06**	**1.98**	**1.94**

Assessment Four Gs 82

Treatment	R1	R2	R3	C1	C2	C3	N1	N2	N3
A (shaded)	9.5	7.4	4.67	3.67	4.55	15.4	6.22	7.22	17.2
U (shaded)	12.0	12.1	1.78	5.67	5.89	11.4	14.43	17.3	29.45
B (shaded)	10.0	10.0	0.56	5.22	7.42	20.87	12.75	19.0	24.65
A (unshaded)	11.7	11.9	0.0	28.1	15.0	24.78	14.3	15.11	27.76
U (unshaded)	22.8	12.8	0.0	29.45	22.76	0.0	23.1	52.3	100
B (unshaded)	4.1	2.76	2.22	34.4	37.76	1.1	32.78	38.3	95.0
SED	**8.12**	**8.94**	**2.56**	**8.61**	**8.43**	**7.16**	**5.4**	**6.45**	**12.75**

Individual leaf layers assessed. R = Rhynchosporium, C = Chlorosis, N = Necrosis

Assessment Five Gs 87

Treatment	Ramularia	Rhyncho	Chlorosis	Necrosis
A (shaded)	10.0	19.33	11.67	20.0
U (shaded)	13.3	33.33	0.0	46.67
B (shaded)	16.67	20.0	1.67	50.0
A (unshaded)	21.67	18.33	0.0	60.0
U (unshaded)	20.0	20.0	0.0	60.0
B (unshaded)	26.0	28.3	0.0	45.67
SED	**5.75**	**16.18**	**2.15**	**13.42**

Appendix 3 for Section 3

Fungicide Trials

Fungicide trials 1999

Aberdeen 1999

Effect of fungicide programme on disease development, necrotic lesions (14 July, GS 85) and yield components of Chariot spring barley

Treatment	% Leaf area infected, Leaf 2					YIELD t/ha @ 15% MC	Yield benefit (t/ha)	Specific Weight (kg/hl)	Screening (<2.5mm) (%)
	Rhyncho Sporium	Brown Spots	Chariot Spots	Total Spots	Green leaf area				
1	8.0	19.0	1.2	21.0	39.2	5.139	-	68.39	13.84
2	0.9	15.5	0.8	16.4	77.4	5.881	0.742	70.68	8.76
3	2.5	9.0	1.1	10.1	79.8	6.093	0.954	70.65	10.43
4	10.4	8.7	1.2	9.9	65.6	5.569	0.430	70.50	12.59
5	11.6	6.8	1.4	8.2	57.7	5.361	0.222	69.58	14.13
6	7.8	8.7	1.2	9.9	69.9	5.674	0.535	70.16	10.95
7	12.2	6.8	1.1	7.8	50.5	5.552	0.413	70.08	11.86
8	7.7	7.4	1.9	9.3	57.0	5.349	0.210	70.29	11.36
9	3.6	11.0	2.2	13.1	69.8	5.855	0.746	70.22	9.40
10	2.5	7.7	1.2	8.9	80.6	5.676	0.537	70.02	11.61
11	5.1	12.5	1.4	13.9	76.7	5.674	0.535	70.19	10.98
12	5.4	8.8	1.6	10.4	75.7	5.880	0.741	70.82	8.88
13	6.0	7.7	1.5	9.2	62.6	5.629	0.490	70.38	12.12
14	4.6	8.4	0.8	9.2	76.5	5.540	0.401	69.81	11.32
15	3.3	5.8	1.4	7.2	79.5	5.929	0.790	71.08	10.02
16	7.6	6.9	1.0	7.8	71.3	5.764	0.625	71.10	8.99
17	7.8	10.8	2.0	12.9	56.2	5.416	0.277	70.12	14.92
18	10.6	14.7	1.6	16.3	39.0	5.409	0.270	69.74	15.23
19	5.6	6.3	1.6	7.9	74.2	5.866	0.727	71.02	8.67
20	7.7	10.0	2.2	12.2	69.4	5.602	0.463	70.00	11.27
SED (57 df)	2.628	1.974	0.608	2.093	7.270	0.1646	-	0.447	1.479
LSD	5.256	3.948	1.216	4.186	14.541	0.3292	-	0.894	2.958
significance	***	***	NS	***	***	***	-	***	***

* = significant at p≤0.05 ** = significant at p≤0.01 *** = significant at p≤0.001 Ns = not significant

Bush 1999

Disease assessment 28 July 1999 Early Milk and crop yields

Code	% Ramularia Flag leaf	% Ramularia Leaf 2	% Green leaf area Flag leaf	% Green leaf area Leaf 2	**T/ha 85% DM**	**MOFC £80**
1	27.0	23.8	25	20	6.68	534
2	18.8	22.5	55	43	7.20	515
3	12.5	5.5	38	68	7.67	513
4	27.0	27.5	38	38	7.14	533
5	20.5	18.3	45	35	6.95	518
6	18.8	18.3	35	43	7.10	530
7	10.3	7.3	60	53	7.04	525
8	0.8	1.3	65	79	7.40	554
9	24.0	28.8	35	30	7.18	554
10	10.5	10.5	56	55	7.21	552
11	16.8	13.8	60	53	7.14	556
12	11.8	7.8	48	65	7.33	542
13	17.0	10.0	55	68	7.53	565
14	20.0	12.5	50	58	7.34	508
15	8.5	5.5	58	73	7.43	514
16	15.0	13.5	54	55	7.28	542
17	26.3	25.0	29	21	6.76	535
18	28.8	33.8	29	20	6.61	523
19	12.0	7.3	58	75	7.57	547
20	22.5	23.8	49	43	7.01	534
	3.25	3.65	9.1	10.5	0.132	10
	<.001	<.001	<.001	<.001	<.001	<.001

MOFC - Margin over fungicide cost at £80/tonne

Morley 1999

Fungicide trial Treatment	t/ha Morley	SPWT	Treatment	Ramularia % Leaf 2 02-Jul-99	GLA % Leaf 2 02-Jul-99	GLA % Leaf 3 02-Jul-99	GLA % Leaf 2 12-Jul-99	Brackling 0-10 score 03-Aug-99
1	5.31	71.3	1	3.0	10.8	0.0	0.0	3.8
2	6.12	72.8	2	0.5	62.5	41.3	4.5	1.8
3	6.51	72.5	3	1.3	65.0	41.3	6.0	2.0
4	6.06	72.2	4	2.4	35.0	2.3	0.0	2.8
5	5.81	72.4	5	1.4	52.5	16.3	0.0	1.3
6	6.07	72.6	6	0.9	57.5	20.0	0.5	1.5
7	6.14	72.4	7	1.9	54.5	15.0	0.6	2.3
8	5.86	72.8	8	1.6	51.8	5.3	0.6	2.5
9	5.89	72.3	9	3.1	41.8	6.5	0.0	2.0
10	6.15	72.5	10	0.9	61.3	23.8	0.3	1.5
11	5.96	72.1	11	2.1	38.8	5.0	0.0	2.8
12	6.13	72.7	12	0.8	67.5	46.3	1.1	1.5
13	6.12	72.3	13	0.7	65.8	29.5	1.4	1.3
14	5.79	72.6	14	1.1	61.3	17.0	0.1	2.0
15	6.10	72.3	15	0.5	60.8	30.5	1.6	1.5
16	6.47	72.7	16	0.6	66.0	30.0	1.0	1.5
17	5.30	71.6	17	3.5	12.5	0.0	0.0	3.3
18	5.38	71.3	18	3.4	10.8	0.0	0.0	3.5
19	6.26	72.5	19	0.3	67.5	41.3	2.6	1.3
20	5.95	72.5	20	2.4	38.8	4.8	0.0	2.8
LSD	0.516	0.61	LSD	1.11	9.72	13.59	2.14	0.87
SE per plot (57 df) ±	0.365	0.43	SE per plot (57 df) ±	0.78	6.88	9.61	1.51	0.62
CV (%)	6.1	0.6	CV (%)	48.7	14.0	51.2	148.2	28.9

Fungicide trials 2000

Aberdeen 2000
No trial this year

Bush 2000

	Mil(1)	Rhy(1)	Ram(1)	Nec(1)	Chl(1)	Mil(2)	Rhy(2)	Ra (2)	Nec(2)	Chl(2)	Rhy (3)	Nec(3)	Chl(3)	GLA1	GLA2	GLA3
Unt	0.0	4.6	7.9	42.5	25.8	0.0	10.8	1.7	83.8	3.8	12.1	87.9	0.0	19.2	0.0	0.0
A	0.0	0.8	5.2	20.5	30.8	0.0	2.7	7.8	47.5	27.5	6.3	93.8	0.0	42.7	14.6	0.0
B	0.0	0.0	5.7	65.8	34.2	0.0	0.0	6.1	50.4	30.8	5.0	89.6	5.4	-5.6	12.7	0.0
C	0.0	2.3	4.0	21.8	30.4	0.0	10.4	2.5	70.0	14.6	10.4	89.6	0.0	41.5	2.5	0.0
D	0.0	1.8	8.6	26.7	43.3	0.0	4.6	4.6	37.7	39.0	12.3	87.7	0.0	19.6	14.2	0.0
E	0.0	0.5	5.3	28.0	33.6	0.0	2.9	3.3	61.9	21.7	11.1	88.9	0.0	32.6	10.2	0.0
F	0.0	0.3	7.1	16.8	29.0	0.0	6.3	5.3	55.4	25.8	10.4	89.2	0.4	46.8	7.3	0.0
G	0.0	2.3	5.3	22.4	27.6	0.0	8.3	3.3	54.7	17.1	15.0	85.0	0.0	42.4	16.7	0.0
H	0.0	2.9	8.8	23.4	39.6	0.0	5.8	4.2	82.9	5.0	9.2	90.8	0.0	25.3	2.1	0.0
J	0.0	0.6	7.8	35.3	23.3	0.0	2.7	6.2	48.3	29.6	9.2	90.8	0.0	33.1	13.3	0.0
K	0.0	0.8	4.3	32.8	39.2	0.0	3.8	4.6	59.6	25.4	8.8	91.3	0.0	23.0	6.7	0.0
L	0.0	0.4	8.2	7.8	42.1	0.0	0.4	6.7	39.6	37.5	8.3	80.0	8.8	41.6	15.8	2.9
M	0.0	0.8	6.5	38.5	25.0	0.0	2.9	7.2	46.7	29.9	10.4	88.8	0.8	29.3	13.3	0.0
N	0.0	0.4	9.2	23.1	29.8	0.0	3.3	5.0	43.3	30.0	8.8	87.9	3.3	37.5	18.3	0.0
P	0.0	1.6	5.1	22.3	40.0	0.0	1.8	5.4	37.9	36.3	8.2	88.1	2.5	31.0	18.6	1.2
Q	0.0	0.0	7.4	2.3	41.7	0.0	1.5	6.1	37.1	42.5	6.3	85.4	7.9	48.7	12.8	0.4
R	0.0	0.9	7.2	18.2	31.3	0.0	16.7	2.5	79.2	5.0	17.1	82.9	0.0	42.5	-3.3	0.0
S	0.0	7.1	8.8	25.8	36.3	0.0	15.4	1.3	81.3	0.8	18.3	81.7	0.0	22.0	1.3	0.0
T	0.0	0.6	8.6	24.3	29.2	0.0	1.4	7.7	40.4	33.3	7.9	84.5	0.4	37.3	17.2	7.2
V	0.0	1.7	8.7	32.8	25.0	0.0	5.4	8.8	56.3	18.8	10.4	89.6	0.0	31.8	10.8	0.0
SED	0	2.147	2.168	14	8.85	0	3.35	2.44	15.7	9.54	2.85	4.76	4.03	12.52	7.61	1.01
Sig level	not sig.	not sig.	not sig.	not sig.	not sig.	not sig.	P<0.001	not sig	P<0.05	P<0.001	P=001	not sig.	not sig.	not sig.	not sig.	not sig.

Morley 2000

Trial number: NAS 1482 ML 2000					
	The effect of treatment on *Rhynchosporium secalis*, Brown rust, 'Chariot spot', physiological speckling and green leaf area (% leaf)				
	Rhyncho	B. rust	Chariot spot	Speckle	GLA
	L1	L1	L1	L1	L1
	%	%	%	%	%
Treatment	28-Jun-00	28-Jun-00	28-Jun-00	28-Jun-00	28-Jun-00
1	2.9	0.2	1.9	0.8	84.3
2	0.1	0.0	1.3	0.4	92.0
3	0.0	0.0	0.4	0.1	95.0
4	0.6	0.0	1.3	0.4	89.3
5	0.6	0.0	1.6	0.5	89.3
6	1.1	0.0	1.2	0.1	89.8
7	0.6	0.0	1.9	0.1	90.8
8	0.6	0.0	1.1	0.2	87.5
9	0.7	0.0	0.6	0.5	90.8
10	0.3	0.0	1.0	0.3	91.3
11	0.1	0.0	1.4	0.1	92.5
12	0.0	0.0	0.3	0.0	95.0
13	0.2	0.1	0.5	0.1	92.5
14	0.0	0.0	0.5	0.0	95.3
15	0.0	0.0	0.3	0.2	92.5
16	0.1	0.0	0.6	0.1	94.3
17	1.7	0.1	1.7	0.6	84.5
18	1.0	0.1	1.6	1.0	84.3
19	0.2	0.0	0.4	0.0	93.0
20	0.8	0.0	1.6	0.6	91.3
LSD	NS	0.09	1.11	0.56	5.59
SE per plot (57 df) ±	1.20	0.06	0.78	0.40	3.95
CV (%)	209.7	283.9	73.9	133.3	4.4

	The effect of treatment on *Rhynchosporium secalis*, Brown rust, 'Chariot spot', physiological speckling and green leaf area (% leaf)				
	Rhyncho	B. rust	Chariot spot	Speckle	GLA
	L2	L2	L2	L2	L2
	%	%	%	%	%
Treatment	28-Jun-00	28-Jun-00	28-Jun-00	28-Jun-00	28-Jun-00
1	4.0	0.6	4.3	2.0	57.5
2	0.1	0.0	3.1	2.0	77.5
3	0.1	0.0	2.0	0.6	82.5
4	2.4	0.0	2.0	1.1	72.3
5	1.8	0.0	2.8	1.6	72.5
6	3.3	0.0	2.5	1.2	72.5
7	2.5	0.0	2.6	0.3	73.8
8	2.9	0.1	2.6	0.6	68.8
9	0.8	0.0	1.8	1.3	76.3
10	0.9	0.0	2.0	0.9	73.8
11	0.3	0.0	2.8	0.4	78.8
12	0.4	0.0	1.4	0.2	81.5
13	0.9	0.0	2.3	0.4	78.0
14	0.1	0.0	1.9	0.2	84.5
15	0.1	0.0	1.4	0.5	78.3
16	0.5	0.0	1.3	0.3	81.3
17	3.3	0.4	2.8	2.1	58.8
18	3.4	0.4	2.5	2.5	58.8
19	0.4	0.0	1.5	0.3	78.8
20	1.6	0.0	2.0	1.6	69.5
LSD	2.54	0.11	1.23	1.00	8.40
DF	57	56	57	57	57
SE per plot ±	1.80	0.08	0.87	0.71	5.94
CV (%)	121.3	103.0	38.4	71.4	8.1

	The effect of treatment on *Rhynchosporium secalis*, Brown rust, 'Chariot spot', physiological speckling and green leaf area (% leaf)				
	Rhyncho	B. rust	Chariot spot	Speckle	GLA
	L3	L3	L3	L3	L3
	%	%	%	%	%
Treatment	28-Jun-00	28-Jun-00	28-Jun-00	28-Jun-00	28-Jun-00
1	6.0	1.1	2.0	0.9	28.8
2	0.1	0.0	0.3	0.8	57.5
3	0.0	0.0	0.2	0.3	65.0
4	1.3	0.0	0.2	0.3	55.0
5	1.8	0.0	0.8	0.4	53.8
6	3.6	0.0	0.4	0.4	45.8
7	2.5	0.0	0.4	0.2	43.8
8	2.3	0.3	0.5	0.6	40.8
9	0.8	0.0	0.5	0.4	50.8
10	0.9	0.0	0.6	0.4	52.0
11	0.6	0.0	0.8	0.4	50.0
12	0.3	0.0	0.3	0.1	57.5
13	1.0	0.0	0.4	0.1	50.0
14	0.3	0.0	0.4	0.2	60.0
15	0.3	0.0	0.3	0.4	53.8
16	0.5	0.0	0.4	0.1	57.5
17	4.0	0.3	0.7	0.8	22.5
18	5.6	0.2	0.5	0.7	26.3
19	0.3	0.0	0.3	0.1	56.3
20	1.5	0.0	0.5	0.5	47.5
LSD	NS	0.19	0.76	NS	8.33
SE per plot (57 df) ±	3.10	0.13	0.54	0.43	5.89
CV (%)	185.8	135.6	106.2	113.0	12.1

	The effect of treatment on *Rhynchosporium secalis*, Brown rust, 'Chariot spot', physiological speckling and Ramularia (% leaf)				
	Chariot spot	Rhyncho	B. rust	Ramularia	Speckle
	L1	L1	L1	L1	L1
	%	%	%	%	%
Treatment	10-Jul-00	10-Jul-00	10-Jul-00	10-Jul-00	10-Jul-00
1	5.0	5.3	0.1	0.1	10.8
2	3.0	0.8	0.0	0.0	7.8
3	1.6	0.5	0.0	0.0	4.8
4	3.0	2.5	0.0	0.0	5.8
5	3.5	3.8	0.0	0.0	2.8
6	2.7	1.3	0.0	0.0	7.0
7	2.3	3.0	0.0	0.0	4.0
8	3.4	3.6	0.0	0.0	4.3
9	2.3	1.6	0.0	0.1	5.3
10	2.8	2.3	0.0	0.0	3.5
11	3.5	0.6	0.0	0.0	3.1
12	1.1	0.4	0.0	0.0	3.0
13	3.3	1.6	0.0	0.0	3.3
14	1.1	0.5	0.0	0.0	2.4
15	1.1	0.9	0.0	0.0	3.5
16	1.6	0.8	0.0	0.0	3.0
17	3.1	2.8	0.1	0.2	8.0
18	3.0	2.4	0.1	0.1	11.0
19	1.5	0.3	0.0	0.0	2.5
20	2.8	2.0	0.0	0.0	4.6
LSD	1.84	2.72	NS	0.06	3.79
SE per plot (57 df) ±	1.30	1.92	0.06	0.04	2.68
CV (%)	50.6	104.5	348.0	208.6	53.6

	The effect of treatment on green leaf area, 'Chariot spot', *Rhynchosporium secalis*, Brown rust and Ramularia (% leaf)				
	GLA	Chariot spot	Rhyncho	B. rust	Ramularia
	L1	L2	L2	L2	L2
	%	%	%	%	%
Treatment	10-Jul-00	10-Jul-00	10-Jul-00	10-Jul-00	10-Jul-00
1	35.0	1.8	8.3	1.4	1.0
2	63.0	2.4	1.1	0.0	0.7
3	67.5	2.4	0.6	0.0	0.3
4	61.3	2.0	3.8	0.0	0.5
5	60.0	2.3	4.8	0.0	0.9
6	57.5	2.8	6.5	0.0	1.0
7	63.5	1.9	5.0	0.0	0.4
8	56.3	3.8	6.3	0.0	0.4
9	61.3	1.3	2.5	0.0	1.0
10	62.5	2.5	3.5	0.0	0.3
11	60.5	3.9	0.7	0.2	1.4
12	71.3	0.9	1.0	0.0	0.0
13	66.3	2.0	3.1	0.0	0.1
14	72.3	1.3	0.8	0.0	0.4
15	65.0	1.4	1.5	0.0	0.0
16	63.3	1.3	1.3	0.0	0.2
17	37.5	2.3	3.4	1.6	1.6
18	37.5	1.6	4.3	2.1	1.9
19	71.3	0.9	0.4	0.0	0.1
20	57.5	1.8	2.6	0.0	0.8
LSD	10.92	1.66	4.50	0.67	0.70
SE per plot (57 df) ±	7.72	1.17	3.18	0.47	0.49
CV (%)	13.0	58.5	104.2	178.8	77.0

	The effect of treatment on physiological speckling green leaf area and brackling (%)				
	Speckle	GLA	GLA	GLA	Brackling
	L2	L2	L3	L1-3	
	%	%	%		%
Treatment	10-Jul-00	10-Jul-00	10-Jul-00	20-Jul-00	14-Aug-00
1	6.5	12.3	0.3	4.0	50.5
2	7.5	61.8	20.5	44.8	31.3
3	2.5	66.3	26.3	45.5	19.8
4	5.3	47.0	6.8	21.5	34.0
5	3.0	47.5	9.5	23.0	40.0
6	3.8	50.0	10.5	16.5	36.3
7	1.8	55.0	8.3	32.0	37.3
8	4.3	50.0	8.3	34.8	41.8
9	5.5	48.8	5.5	27.3	30.5
10	2.8	56.3	14.8	36.0	31.3
11	3.6	50.0	4.0	18.5	36.5
12	1.0	58.8	12.3	32.5	8.0
13	1.8	57.0	15.0	38.3	16.3
14	1.4	60.0	14.8	38.8	10.0
15	2.4	57.0	18.0	43.3	10.0
16	1.3	60.0	19.3	35.3	6.8
17	4.3	16.3	0.3	6.0	48.8
18	10.0	15.0	0.0	4.5	58.0
19	1.6	63.8	26.8	49.0	9.3
20	4.5	48.0	7.0	13.0	39.0
LSD	4.13	10.90	7.91	12.17	29.54
SE per plot (57 df) ±	2.92	7.71	5.59	8.61	20.89
CV (%)	78.4	15.7	49.1	30.5	70.2

	The effect of treatment on grain yield (t/ha at 85% dm) and specific grain weight (kg/hl)

	Yield	Specific weight
	at 85% dm	
	t/ha	kg/hl
Treatment	14-Aug-00	04-Sep-00
1	5.82	70.5
2	6.61	71.7
3	6.71	71.9
4	6.06	71.1
5	6.35	71.4
6	6.32	71.2
7	6.43	71.7
8	6.30	71.7
9	6.22	71.4
10	6.44	71.5
11	5.98	71.0
12	6.19	71.6
13	6.47	71.8
14	6.46	71.9
15	6.37	71.7
16	5.99	71.6
17	5.55	70.4
18	5.81	70.7
19	6.41	70.8
20	6.05	71.3
LSD	0.549	0.83
SE per plot (54 df) ±	0.388	0.59
CV (%)	6.2	0.8

Fungicide trials 2001

Aberdeen 2001

Effect of fungicide on disease development, necrotic lesions (17 July, GS 83) and yield components of Chariot spring barley 2001

Treat ment	% Leaf area infected, Whole plant					YIELD t/ha @ 15% MC	Yield benefit (t/ha)	Specific Weight (kg/hl)	Screening (<2.5mm) (%)
	Rhyncho Sporium	Brown Spots	Chariot Spots	Yellowing/ Chlorosis	Green leaf area				
1	0.5	0	20.1	14.5	64.9	6.513	-	73.37	5.7
2	.2	0	17.9	14.3	67.5	6.733	0.220	73.70	4.6
3	0	0	12.5	13.8	73.8	6.893	0.380	73.59	5.0
4	0	0	15.8	13.8	70.4	6.855	0.342	73.56	5.4
5	0.3	0	18.0	13.3	68.3	6.653	0.140	73.40	5.6
6	0.5	0	18.1	12.0	69.4	6.625	0.112	73.21	5.2
7	0.2	0	15.9	15.7	68.2	6.418	-0.095	73.63	5.1
8	1.2	0	12.8	12.7	73.3	6.717	0.204	73.55	5.0
9	1.1	0	14.2	10.5	74.2	6.690	0.177	73.90	4.9
10	0.4	0	21.3	14.1	64.2	6.673	0.160	73.68	5.3
11	0.8	0	18.5	14.3	66.4	6.653	0.140	73.14	5.6
12	0.4	0	13.8	12.7	73.2	6.693	0.180	73.29	4.9
13	0	0	13.8	12.8	73.4	6.705	0.192	73.70	4.4
14	0.1	0	16.5	12.5	70.9	6.785	0.273	73.40	4.0
15	0.2	0	17.0	14.1	68.7	6.885	0.372	73.38	4.5
16	0.5	0	14.3	13.7	71.5	6.815	0.302	73.49	4.5
17	0.4	0	22.8	14.3	62.5	6.540	0.027	73.39	5.6
18	1.2	0	21.0	13.2	64.6	6.583	0.070	73.54	6.1
19	0.1	0	15.5	16.8	67.6	6.750	0.237	73.76	4.9
20	0.4	0 0	13.4	13.0	73.2	6.645	0.132	73.45	5.6
SED (57 df)	0.39	-	2.439	1.51	3.18	0.0911	-	0.208	0.58
LSD	0.78	-	4.992	3.02	6.37	0.1825	-	0.418	1.17
Signif icance	*	-	***	Ns	**	***	-	Ns	Ns

* = significant at p≤0.05 ** = significant at p≤0.01 *** = significant at p≤0.001 Ns = not significant

Effect of fungicide on disease development, necrotic lesions (02 August, GS 83-85) and yield components of Chariot spring barley 2001

	% Leaf area infected, Leaf 2							YIELD t/ha @ 15% MC	Yield benefit (t/ha)	Specific Weight (kg/hl)	Screen-ing <2.5mm (%)
	Rhyncho sporium	Septoria	Ramularia	Brown Spots	Chariot Spots	Total Spots	Green leaf area				
1	0.2	2.2	6.0	2.6	8.9	19.8	20.5	6.513	-	73.37	5.7
2	0.1	2.8	5.3	2.5	8.3	19.0	19.1	6.733	0.220	73.70	4.6
3	0	0.5	3.0	1.6	6.0	11.2	36.3	6.893	0.380	73.59	5.0
4	0.02	0.2	4.3	2.9	12.8	20.2	23.8	6.855	0.342	73.56	5.4
5	0.1	2.2	6.7	2.5	9.2	20.7	19.4	6.653	0.140	73.40	5.6
6	0.02	1.9	4.4	3.8	7.6	17.7	28.4	6.625	0.112	73.21	5.2
7	0	2.1	3.9	2.7	10.2	18.8	21.1	6.418	-0.095	73.63	5.1
8	0	1.0	3.2	3.1	8.5	15.9	30.0	6.717	0.204	73.55	5.0
9	0	0.9	3.0	3.2	7.3	14.3	22.7	6.690	0.177	73.90	4.9
10	0.2	0.9	4.5	2.3	9.3	17.0	25.4	6.673	0.160	73.68	5.3
11	0.05	1.3	4.6	1.6	7.5	15.0	26.4	6.653	0.140	73.14	5.6
12	0.1	0.5	3.1	4.3	8.4	16.4	30.0	6.693	0.180	73.29	4.9
13	0.3	0.9	4.4	1.2	8.0	14.6	28.9	6.705	0.192	73.70	4.4
14	0	1.6	4.7	3.0	6.8	16.0	25.2	6.785	0.273	73.40	4.0
15	0	0.7	5.5	3.4	8.0	17.6	24.3	6.885	0.372	73.38	4.5
16	0	0.9	4.1	4.7	6.8	16.6	31.8	6.815	0.302	73.49	4.5
17	0	2.7	3.8	2.7	6.8	16.0	13.4	6.540	0.027	73.39	5.6
18	0.3	3.3	3.5	2.8	6.3	16.0	17.5	6.583	0.070	73.54	6.1
19	0	1.4	3.8	3.0	7.6	15.7	29.0	6.750	0.237	73.76	4.9
20	0	2.5	4.4	1.6	6.9	15.4	25.0	6.645	0.132	73.45	5.6
Sed (57 df)	0.10	0.54	1.28	1.28	2.13	2.62	6.48	0.0911	-	0.208	0.58
LSD	0.20	1.08	2.57	2.56	4.26	5.24	12.98	0.1825	-	0.418	1.17
significance	Ns	***	Ns	Ns	Ns	Ns	Ns	***	-	Ns	Ns

* = significant at p≤0.05 ** = significant at p≤0.01 *** = significant at p≤0.001 Ns = not significant

Bush 2001
24/Jul/01 Gs 78

	Mil(1)	Rhy(1)	Ram(1)	Nec(1)	Chl(1)	Rhy(2)	Ram (2)	Nec(2)	Chl(2)	Rhy (3)	Ram(3)	Nec(3)	Chl(3)	GLA1	GLA2	GLA3
Unt	0	22.67	1.42	13.67	6.33	26.4	1.67	20.17	6.83	30.33	1.50	30.33	8.25	55.91	44.93	29.59
A	0	2.58	0.42	9.58	3.75	1.3	1.83	11.75	4.17	0.42	1.33	9.17	6.58	83.67	80.95	82.5
B	0	1.25	1.33	7.92	5.42	0.8	1.45	7.58	5.58	0.42	0.50	4.25	5.75	84.08	84.59	89.08
C	0	0.33	0.17	11.92	7.58	0.2	0.33	4.75	2.50	0.00	0.17	2.42	2.25	80	92.22	95.16
D	0	2.83	0.42	8.83	2.75	0.9	1.25	11.33	4.00	0.42	0.75	9.08	5.42	85.17	82.52	84.33
E	0	3.67	0.50	10.83	3.92	14.8	1.42	11.83	7.17	16.08	0.83	10.08	8.25	81.08	64.78	64.76
F	0	4.67	0.33	10.67	6.08	10.1	0.92	13.83	9.67	11.33	0.83	14.58	14.25	78.25	65.48	59.01
G	0	7.25	0.17	8.92	6.50	13.8	0.08	8.25	6.75	10.83	0.00	3.42	7.42	77.16	71.12	78.33
H	0	2.33	0.67	6.58	3.92	14.4	0.33	7.17	6.08	13.08	0.50	9.42	9.08	86.5	72.02	67.92
J	0	7.08	0.67	7.67	5.25	7.5	0.92	14.42	7.67	4.58	0.00	5.00	8.00	79.33	69.49	82.42
K	0	1.17	0.50	7.92	8.00	3.2	0.25	10.42	9.00	1.83	2.17	5.50	6.92	82.41	77.13	83.58
L	0	0.92	0.58	7.92	4.17	1.8	1.25	8.58	4.83	0.50	0.17	3.17	2.58	86.41	83.54	93.58
M	0	1.58	0.33	4.50	3.17	0.4	1.25	7.08	3.42	1.50	0.50	4.42	4.92	90.42	87.85	88.66
N	0	2.33	0.25	6.00	3.42	3.1	0.67	8.08	4.42	0.00	0.75	6.42	4.50	88	83.73	88.33
P	0	1.25	0.42	7.00	2.50	0.2	0.50	5.83	3.08	0.17	0.25	2.58	1.67	88.83	90.39	95.33
Q	0	5.33	0.58	8.83	5.92	1.6	1.08	8.58	6.83	3.58	0.17	3.75	5.58	79.34	81.91	86.92
R	0	3.58	0.67	15.17	5.92	5.7	1.50	16.25	7.00	4.50	2.17	6.08	7.58	74.66	69.55	79.67
S	0	33.58	0.33	17.08	5.33	40.8	1.42	17.92	9.75	23.25	0.00	30.83	20.00	43.68	30.11	25.92
T	0	0.50	0.67	6.50	5.33	2.2	1.25	6.00	5.42	0.00	0.33	3.92	2.50	87	85.13	93.25
V	0	2.42	0.67	8.58	5.08	3.8	1.58	13.67	8.50	1.00	1.33	10.33	8.25	83.25	72.45	79.09
SED	0	4.26	0.48	2.02	1.63	6.96	0.62	2.57	1.88	5.99	0.84	5.82	4.45	5.84	8.16	11.08
Sig level	not sig.	P<0.001	not sig.	P<0.001	P=0.05	P<0.001	not sig	P<0.001	P<0.005	P<0.001	not sig.	P<0.001	P<0.05	P<0.001	P<0.001	P<0.001

Morley 2001

Treatment	Speckle % L1 26-Jul-01	Chariot Spot % L1 26-Jul-01	Rhyncho % L1 26-Jul-01	Speckle % L2 26-Jul-01	Chariot Spot % L2 26-Jul-01
1	30.5	5.5	2.5	28.8	8.8
2	24.8	3.8	1.4	18.8	6.5
3	15.5	5.0	1.3	13.0	7.8
4	19.3	5.0	1.0	12.0	5.8
5	16.0	3.3	1.8	13.5	4.8
6	17.5	6.0	1.5	17.0	6.5
7	17.3	4.3	1.0	12.5	4.8
8	15.0	4.0	0.8	12.0	4.8
9	13.0	3.3	1.0	9.5	5.5
10	17.0	5.5	1.3	11.0	5.0
11	11.8	3.0	0.8	8.5	6.3
12	13.5	3.5	1.0	8.8	4.0
13	16.5	5.3	1.4	9.8	3.8
14	13.8	3.0	1.3	10.0	5.5
15	10.8	3.0	0.7	6.3	4.3
16	10.8	2.8	0.9	6.5	2.8
17	20.0	5.5	1.8	16.8	7.3
18	14.0	4.0	1.3	19.8	6.0
19	11.3	3.8	0.9	8.8	4.5
20	18.5	3.5	1.3	17.8	5.3
LSD	7.82	NS	0.79	6.85	2.83
SE per plot (57 df) ±	5.53	1.85	0.56	4.85	2.00
CV (%)	33.9	44.6	45.6	37.2	36.5

Treatment	Rhyncho % L2 26-Jul-01	GLA % L2 26-Jul-01	GLA % L3 26-Jul-01	GLA % L2 01-Aug-01	Yield T/ha 31-Aug-01	Specific weight Kg/hl 08-Sep-01
1	3.5	40.0	20.0	1.5	4.62	65.6
2	0.4	55.3	47.0	40.0	4.86	65.9
3	0.2	59.3	50.3	30.8	5.04	66.0
4	0.5	62.5	55.0	48.3	4.78	66.3
5	1.5	51.8	40.0	23.0	4.71	65.9
6	1.5	53.8	43.3	20.8	4.71	65.9
7	0.9	58.8	51.3	36.3	4.80	65.4
8	0.4	60.0	42.8	25.5	4.92	66.1
9	0.3	58.0	49.3	37.0	4.92	66.4
10	0.6	62.0	51.3	35.8	4.69	65.9
11	0.4	63.0	51.3	28.8	4.89	65.9
12	0.2	63.0	52.0	40.8	4.86	65.9
13	0.3	62.5	51.3	32.5	4.91	65.9
14	0.3	63.8	53.0	43.8	5.02	66.0
15	0.2	66.3	55.8	37.5	4.81	65.6
16	0.2	70.0	58.3	43.0	5.06	65.5
17	1.4	50.0	35.0	27.0	4.55	66.0
18	2.3	43.8	24.3	6.5	4.71	66.0
19	0.2	66.3	56.5	50.0	4.84	65.9
20	0.7	48.8	27.5	10.3	4.72	65.4
LSD	0.87	6.49	7.94	11.74	NS	NS
DF	57	57	57	57	53	0.43
SE per plot ±	0.61	4.59	5.62	8.30	0.280	0.7
CV (%)	78.7	7.9	12.3	26.8	5.8	

Appendix 4 for Section 4

Variety trials 1999

Aberdeen

Table 1 Disease development, necrotic lesions (Leaf 2, 16 July, GS 85) and yield components of spring barley varieties 1999

		% Leaf area affected Leaf 2						YIELD t/ha @15%MC	Yield Benefit (t/ha)	Specific Weight (kg/hl)	Screenings (<2.5mm) (%)
		Mildew	Rhyncho sporium	Ramularia	Brown Spots	Target Spots	Green Leaf Area				
Treatment											
Prisma	1	3.0	4.6	0	13.3	1.0	30.8	4.624	-	66.45	9.7
Prisma	2	4.9	0.8	0	4.0	0.6	78.7	4.946	0.322	67.50	6.9
Prisma	3	1.9	1.5	0	5.5	1.6	72.1	5.188	0.564	68.09	5.8
Optic	1	0.2	10.5	0	10.2	0.6	56.6	4.849	-	67.15	21.5
Optic	2	1.4	2.0	0	3.8	0.5	83.2	5.640	0.791	69.01	13.8
Optic	3	1.4	0.3	0	4.1	0.4	84.5	6.244	1.395	70.05	8.4
Chariot	1	0	5.0	0	22.4	0.3	21.2	4.822	-	69.58	16.8
Chariot	2	0.5	1.0	0	12.6	1.8	60.0	5.294	0.472	70.82	12.1
Chariot	3	0.6	1.1	0	13.1	3.1	68.6	5.448	0.626	70.82	8.1
Cooper	1	0.5	1.8	0	12.0	2.7	52.9	4.763	-	67.68	27.3
Cooper	2	1.1	0.4	0	6.1	0.5	53.9	5.254	0.491	69.35	17.6
Cooper	3	0.3	0.5	0	4.4	0.8	70.4	5.582	0.819	70.36	12.4
Century	1	2.0	0	0	30.1	2.6	40.4	5.378	-	67.52	21.0
Century	2	3.7	0.1	0	10.6	5.7	64.3	5.770	0.392	68.94	13.5
Century	3	1.8	0.1	0	6.7	3.2	80.2	6.577	1.199	69.42	11.3
Newgrange	1	0.4	1.4	0	20.0	1.8	53.9	5.308	-	67.01	11.4
Newgrange	2	0.1	0.6	0	4.6	0.7	63.3	5.691	0.383	68.62	9.4
Newgrange	3	0.1	0.8	0	6.8	1.4	67.6	5.779	0.471	69.19	6.1
Delibes	1	1.8	1.4	0	16.3	1.0	57.0	5.144	-	66.76	13.7
Delibes	2	5.9	0.2	0	5.7	0.2	74.8	5.446	0.302	66.84	12.4
Delibes	3	1.7	0.8	0	6.3	0.7	81.4	5.748	0.604	67.40	12.4
Henni	1	0	13.2	0	4.1	0.2	12.4	4.411	-	64.29	34.1
Henni	2	0.8	4.4	0	1.4	0.2	70.2	5.172	0.761	66.05	22.2
Henni	3	0.1	5.1	0	2.1	0.3	68.9	5.661	1.250	67.44	17.2
SED (69 df)		1.02	2.01	-	3.41	0.63	7.83	0.187	-	0.596	1.65
LSD		2.04	4.02	-	6.83	1.27	15.66	0.374	-	1.192	3.30
Significance		Ns	Ns	-	*	***	***	*	-	Ns	***
Significance var.		***	***	-	***	***	***	***	-	***	***
Significance treat.		**	***	-	***	Ns	***	***	-	***	***

* = significant at p≤0.05 ** = significant at p≤0.01 *** = significant at p≤0.001 Ns = not significant

Edinburgh 1999

Summary

Date:	19/07/1999	GS	77-80			Yield (g/plot)	Yield (kg/ha)
	Mildew	Rhyncho	Chlorosis	Necrosis	GLA	at 85% DM	
Prisma (U)	0	0.83	0.00	99.17	0.00	16.42	5367.87
Prisma (Punch + Opus)	0	0.42	19.83	35.00	44.75	20.41	6667.58
Prisma (Amistar)	0	0.92	22.75	21.83	54.50	21.22	6934.95
Optic (U)	0	20.00	0.00	80.00	0.00	14.12	4615.68
Optic (Prisma + Opus)	0	0.00	7.58	26.17	66.25	19.58	6398.59
Optic (Amistar)	0	0.92	9.00	12.58	77.50	20.54	6712.90
Chariot (U)	0	4.17	1.25	94.58	0.00	16.11	5267.26
Chariot (Punch + Opus)	0	0.00	11.75	49.17	39.08	19.61	6411.48
Chariot (Amistar)	0	1.08	14.67	29.75	54.50	20.32	6644.14
Cooper (U)	0	0.00	0.00	100.00	0.00	15.59	5102.71
Cooper (Punch + Opus)	0	1.83	16.50	20.75	60.92	19.35	6324.16
Cooper (Amistar)	0	0.00	23.08	26.17	50.75	20.05	6554.91
Century (U)	0	0.17	1.25	95.83	2.75	17.25	5640.01
Century (Punch + Opus)	0	0.00	10.67	26.83	62.50	19.38	6335.51
Century (Amistar)	0	0.00	9.92	12.50	77.58	20.61	6735.40
Newgrange (U)	1.5	1.25	1.33	95.42	0.50	16.79	5487.64
Newgrange (Punch + Opus)	10.40	0.00	13.33	38.33	37.92	19.05	6225.56
Newgrange (Amistar)	0	1.17	9.42	17.08	72.33	20.89	6826.83
Delibes (U)	0	0.42	4.92	79.17	15.50	16.82	5498.29
Delibes (Punch + Opus)	0	0.50	11.92	27.17	60.42	19.57	6397.73
Delibes (Amistar)	0	1.00	10.67	11.92	76.42	21.02	6873.08
Henni (U)	0	2.08	0.00	97.92	0.00	16.63	5435.24
Henni (Punch + Opus)	0	0.42	13.92	15.58	70.08	21.38	6994.37
Henni (Amistar)	0	1.67	15.58	13.25	69.50	22.79	7447.24

Variety Trials 2000

Aberdeen
2. Year 2, 2000

2000

This year was a very difficult season in the north-east of Scotland. The weather in early spring was very wet but the crop was sown in early April during a dry spell, several days prior to flooding throughout Aberdeenshire. The cool, unsettled weather in spring slowed the growth of the crop but there was more rapid growth in mid-summer. The weather throughout the season continued to be unsettled and generally dull, with very little sunshine. The season ended prematurely as poor rooting conditions early in the season made the crop more susceptible to soil moisture deficits and there was a rapid loss of leaf in late July/early August. Despite this the crops did not fully ripen until the end of September.

<u>Foliar diseases , 2000</u>

Mildew levels were low on all varieties throughout the season, <1.5% LAI. Levels of Rhynchosporium were low (<5% LAI) for most of the season, with varieties Chariot and Optic showing the highest levels. By mid-July (GS 81/83), levels of Rhynchosporium in untreated plots of Chariot had increased to a maximum of 8.6% LAI on Leaf 2, but levels in all other varieties/treatments remained below 4% LAI. Application of a fungicide tended to reduce Rhynchosporium infection but this was significant in Chariot only.

<u>Ramularia spots, Target spots, Abiotic spots and Green Leaf Area, 2000</u>

Ramularia appeared late in the season, during mid-July to early August (GS 81-91), when the crop was ripening and senescing. The spotting symptoms associated with this disease were most severe on leaves that were completely senescent and as a result tended to occur after most disease assessments were complete. During mid-July, Ramularia was most severe in the untreated plots of varieties Pewter (13.8% LAI, Leaf 2) and Chariot (9.2% LAI, Leaf 2), with Optic, Decanter and Berwick all having similar levels (5-6%) (two weeks later levels on Chariot were 30% but due to complete plant death it was no longer possible to see Ramularia in untreated plots of Pewter). Fungicide application significantly reduced Ramularia in both Pewter and Chariot; there were no differences between fungicide products.

Levels of abiotic brown spotting were very low (<0.3% LAI) in all varieties from GS 31 and remained so for most of the season. The highest levels of brown spotting occurred in Chariot in mid-July, when only 3.8% of the surface area of Leaf 2 was affected (Table 8). Fungicide application reduced the levels of brown spotting slightly.

Low levels of Target/Midas spot (<1%) were present in most varieties from GS 31 and remained so for the whole season. Target spotting was most obvious on the variety Berwick, which could easily be picked out in the field because of this. Target spotting on Berwick peaked in mid-June (GS 45/49).

Fungicide application actually increased target spotting on Berwick, particularly the triazole base programme.

Chariot had the lowest green leaf area remaining at GS 81/83 (30.1% Leaf 2), a result of the Rhynchosporium, Ramularia, abiotic brown spotting and the yellowing of the leaf associated with the distinct abiotic spotting of this variety. Berwick and Pewter also lost a considerable amount of green leaf area. Fungicide application significantly increased green leaf area in all varieties. There were no differences between any of the fungicide programmes, but in general the triazole programme gave the largest improvement in green leaf area.

Target spotting on Berwick, mid-June (GS 45/49), 2000

Treatment	**Target Spots (% LAI)**
untreated	4.3
Triazole	8.2
Strobilurin	6.5
½ Strobilurin	6.4
LSD	1.11

<u>Yield and Seed Quality, 2000</u>

Berwick was the highest yielding variety this season, with a yield average of 7.253 t/ha. Decanter was the lowest yielding variety, with a yield average of 5.986 t/ha, but untreated Chariot gave the lowest yield (5.453 t/ha). Despite the triazole fungicide programme giving the largest increase in green leaf area the two strobilurin based programmes gave slightly higher yields than the triazole.

Yields of Chariot and Optic were increased by all fungicide programmes, a result of increased grain size and a reduction in screenings (significant reduction in Optic). The yields of Pewter and Berwick were increased by fungicide application, but this increase was not significant with the triazole fungicide, despite a 30% increase in green leaf area. Grain size and screenings in these two varieties were unaffected by fungicide treatment. A 20% increase in green leaf area in Decanter from application of fungicide was not translated to an increased yield or grain size. The screenings in Decanter were very high, 43% in untreated plots and the application of a strobilurin fungicide actually increased the level of screenings.

Edinburgh 2000

Date:	19-Jul-00	GS	78				
SUMMARY		Mildew	Rhyncho	Ramularia	Necrosis	Chlorosis	GLA
Chariot							
Untreated		0	31.7	25.8	11.3	14.6	16.7
High Rate Strob.		0	2.0	5.8	5.3	11.0	75.9
Low rate Strob.		0	1.1	9.0	7.8	16.2	65.9
Triazole prog.		0	2.8	6.8	6.3	24.4	59.8
Optic							
Untreated		0	17.3	14.1	7.7	17.1	43.9
High Rate Strob.		0	0.3	2.1	1.5	7.0	89.1
Low rate Strob.		0	0.6	3.8	2.0	11.9	81.7
Triazole prog.		0	2.9	1.8	3.0	7.5	84.8
Decanter							
Untreated		0	30.4	12.1	10.4	16.3	30.8
High Rate Strob.		0	0.0	1.8	2.1	12.3	83.8
Low rate Strob.		0	0.3	2.8	1.8	15.3	79.8
Triazole prog.		0	3.5	1.2	4.8	32.5	58.1
Pewter							
Untreated		0	7.3	24.8	23.5	21.3	23.2
High Rate Strob.		0	1.2	5.4	3.3	35.4	54.7
Low rate Strob.		0	1.2	4.9	1.8	50.8	41.3
Triazole prog.		0	3.2	2.5	8.0	45.8	40.5
Berwick							
Untreated		0	20.4	9.8	6.1	29.6	34.1
High Rate Strob.		0	0.3	4.1	2.2	22.1	71.3
Low rate Strob.		0	0.3	4.8	2.6	18.6	73.8
Triazole prog.		0	2.2	2.3	9.8	23.3	62.6

Variety Trials 2001
Aberdeen
2001

Disease development, necrotic lesions (Leaf 2, 18 July, GS 81-83) and yield components of spring barley varieties 2000

		% Leaf area infected, Leaf 2							YIELD	Yield	Specific	Screenings
		Mildew	Rhyncho sporium	Net Blotch	Ramularia	Brown spots	Target Spots	Green Leaf Area	t/ha @ 15% MC	Benefit (t/ha)	Weight (kg/hl)	(<2.5 mm) (%)
Treatment												
Chariot	1	0	8.6	0.4	9.2	5.0	0.1	30.1	5.453	-	67.89	15.8
Chariot	2	0.02	0.5	0.8	2.9	3.7	0.1	78.8	6.116	0.663	68.27	11.4
Chariot	3	0.03	0.9	1.1	2.0	3.0	0.4	62.9	6.253	0.800	68.37	11.2
Chariot	4	0.14	0.9	1.2	4.1	3.6	0.1	70.0	6.273	0.820	68.32	13.4
Optic	1	0.08	1.9	1.9	6.4	2.9	0.3	57.3	5.527	-	63.73	37.8
Optic	2	0.11	0.9	0.3	1.2	1.9	0.1	79.7	6.667	1.140	66.04	19.5
Optic	3	0.02	0.8	0.3	2.3	2.0	0.2	84.2	6.580	1.053	65.33	24.0
Optic	4	0.2	0.7	0.6	1.8	2.0	0.4	81.1	6.543	1.016	65.68	21.5
Decanter	1	0.36	1.9	1.1	5.3	4.2	0.2	51.8	5.858	-	64.34	43.2
Decanter	2	0.13	1.4	0.4	1.3	2.0	0.4	75.6	6.116	0.258	64.75	38.2
Decanter	3	0	0.7	0.8	0.9	2.5	0.1	75.3	6.039	0.181	64.07	45.3
Decanter	4	0.22	1.1	0.7	0.9	2.6	0.2	76.8	5.931	0.073	64.31	42.5
Pewter	1	0	0.4	4.4	13.8	3.3	0.2	41.3	6.714	-	64.90	12.7
Pewter	2	0	0.6	0.4	0.3	2.3	0.1	77.6	6.896	0.182	65.39	13.3
Pewter	3	0	1.1	0.9	1.3	2.8	0.3	65.9	7.144	0.430	65.53	11.9
Pewter	4	0	0.6	1.6	1.6	2.4	0.2	62.0	7.338	0.624	65.35	10.6
Berwick	1	0	3.6	1.7	5.1	5.3	0.8	36.0	6.968	-	68.63	10.5
Berwick	2	0.07	0.8	0.7	0.6	2.7	1.0	68.4	7.237	0.269	68.47	12.0
Berwick	3	0	0.4	0.3	0.9	2.6	0.6	68.4	7.382	0.414	68.81	11.1
Berwick	4	0.02	0.8	0.3	1.2	2.2	0.7	72.1	7.425	0.457	68.78	11.0
SED (57 df)		0.10	2.31	1.07	2.33	0.93	0.20	9.72	0.188		0.688	3.92
LSD		0.20	4.61	2.14	4.66	1.86	0.40	19.44	0.376		1.376	7.84
significance		Ns	Ns	Ns	Ns	Ns	Ns	Ns	*		Ns	Ns
Signif. var.		**	Ns	*	Ns	*	***	**	***		***	***
Signif.treat.		Ns	*	***	***	***	Ns	***	***		Ns	*

* = significant at p≤0.05 ** = significant at p≤0.01 *** = significant at p≤0.001 Ns = not significant

Disease development, necrotic lesions (Leaf 2, 27 July, GS 83-85) and yield components of spring barley varieties 2001

		% Leaf area affected, Leaf 2				YIELD	Yield	Specific	Screenings
		Ramularia	Brown Spots	Target Spots	Green Leaf Area	t/ha @15%MC	Benefit (t/ha)	Weight (kg/hl)	(<2.5mm) (%)
Treatment									
Berwick	1	0.5	0.8	3.6	65.7	5.170	-	70.54	2.2
Berwick	2	0.2	1.1	3.9	72.6	5.150	0.020	70.21	2.6
Berwick	3	0.03	0.4	4.9	76.1	5.423	0.253	70.44	2.3
Berwick	4	0.2	0.4	5.7	76.7	5.145	-0.025	70.40	2.2
Chariot	1	2.3	17.1	0	57.0	5.190	-	70.56	2.5
Chariot	2	0.7	12.4	0	69.7	4.988	-0.202	70.12	2.6
Chariot	3	0.4	5.4	0.1	73.4	5.188	-0.002	70.78	2.4
Chariot	4	0.4	11.8	0	68.4	5.168	-0.022	70.77	2.5
County	1	0.5	3.0	0.2	83.5	5.652	-	70.13	3.3
County	2	0.8	4.6	0	76.6	5.975	0.323	70.00	2.7
County	3	0.2	4.4	0	74.0	5.970	0.318	69.93	2.6
County	4	0.3	4.8	0	76.7	5.947	0.295	69.86	3.0
Decanter	1	1.2	3.8	0.7	71.0	5.470	-	70.40	5.6
Decanter	2	0.6	2.6	3.0	75.6	5.528	0.058	70.30	5.3
Decanter	3	0.1	4.1	0.1	80.7	5.788	0.318	70.28	5.1
Decanter	4	0.2	1.2	0.4	78.2	5.445	-0.025	70.21	4.2
Optic	1	0.5	2.7	0.1	81.5	5.480	-	70.46	2.3
Optic	2	0.1	1.8	0	85.8	5.477	-0.003	70.52	2.3
Optic	3	0	1.8	0	90.4	5.463	-0.017	70.28	2.2
Optic	4	0.2	2.2	0	85.0	5.553	0.073	70.50	2.2
Pewter	1	1.0	1.8	0	69.2	5.350	-	67.90	2.0
Pewter	2	0.7	2.1	0	70.3	5.288	-0.062	67.58	1.8
Pewter	3	0.1	1.4	0	65.1	5.450	0.100	67.80	2.2
Pewter	4	0.5	2.1	0	72.5	5.200	-0.150	67.64	2.1
SED (69 df)		0.32	0.72	0.77	7.10	0.159	-	0.309	0.45
LSD		0.64	1.45	1.54	14.20	0.318	-	0.618	0.90
Significance		*	Ns	Ns	Ns	Ns	-	Ns	Ns
Significance var		***	***	***	***	***	-	***	***
Significance treat		***	Ns	Ns	Ns	Ns	-	Ns	Ns

* = significant at p≤0.05 ** = significant at p≤0.01 *** = significant at p≤0.001 Ns = not significant

Edinburgh 2001

SUMMARY

	Rhyncho	Ramularia	Necrosis	Chlorosis
Chariot Early Treatment (Amistar + Unix)	2.83	3.42	28.2	21.8
Chariot Two Early sprays (Amistar + Unix)	0	2.5	42.7	21.7
Chariot Early Spray + Late Spray (Amistar + Unix)	0.42	4.67	24.3	35
Chariot Early Spray + Late Spray (Amistar + Unix+Corbel)	0.25	1.58	59.3	23.3
Optic Early Treatment (Amistar + Unix)	0	2.25	48.6	9.8
Optic Two Early sprays (Amistar + Unix)	0	2.08	29.4	13.9
Optic Early Spray + Late Spray (Amistar + Unix)	0	2.42	36.8	19.6
Optic Early Spray + Late Spray (Amistar + Unix+Corbel)	0	1.67	40.9	23.4
Decanter Early Treatment (Amistar + Unix)	0	0.67	52.7	13.8
Decanter Two Early sprays (Amistar + Unix)	0	1.42	46.3	14.6
Decanter Early Spray + Late Spray (Amistar + Unix)	0	1.08	49.2	27.5
Decanter Early Spray + Late Spray (Amistar + Unix+Corbel)	0	0.58	40.8	29.6
Pewter-Early Treatment (Amistar +Unix)	0	1.25	61.7	18.8
Pewter Two Early sprays (Amistar + Unix)	0	3.42	16.2	24.7
Pewter Early Spray + Late Spray (Amistar + Unix)	0	2.33	42.5	25.8
Pewter Early Spray + Late Spray (Amistar + Unix+Corbel)	0	2.83	34.8	32.9
Berwick Early Treatment (Amistar + Unix)	0	1.5	71.8	10.4
Berwick Two Early sprays (Amistar + Unix)	0	3.33	38.5	17.1
Berwick Early Spray + Late Spray (Amistar + Unix)	0	0.83	55	15
Berwick Early Spray + Late Spray (Amistar + Unix+Corbel)	0	2.33	30.8	35.7
County (Early Treatment (Amistar + Unix)	0	1.75	44.8	19.6
County Two Early sprays (Amistar + Unix)	0	12.25	41.7	33.3
County Early Spray + Late Spray (Amistar + Unix)	0	2.83	42.5	27.1
County Early Spray + Late Spray (Amistar + Unix+Corbel)	0	3.58	23.4	22.8
sed	0.821	3.391	19.27	9.59

Acknowledgements

We would like to thank New Farm Crops for their support in carrying out this project. In particular Mike Collins who has provided a great deal of support throughout the period of the project.

We would also like to thank the members of the barley spot group from Norway, Ireland, Germany, and Austria for attending regular meetings and contributing so much throughout the period of the project and hopefully in future collaboration.