TOWARDS AN INTEGRATED DISEASE RISK ASSESSMENT SYSTEM FOR WINTER BARLEY

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ABSTRACT

A prototype Integrated Disease Risk (IDR) system for winter barley is outlined. It is based on a system first developed for winter wheat diseases. Four factors are integrated in equations for each of the main foliar diseases of winter barley. Values for each factor are determined from tables and inserted into IDR equations. The resulting score for each disease relates directly to the fungicide dose. Preliminary evaluation of the system has shown it to be user friendly and to result in acceptable levels of disease control.

INTRODUCTION

Deciding whether or not to apply a fungicide to winter barley and if so what dose to apply is a complex decision. Many factors influence the decision making process. The majority of factors related to such decisions have been listed by Paveley & Lockley (1993) and Wale (1994). However, the most important are probably inoculum, weather conditions, the disease resistance ratings of the variety grown and the crop sensitivity (sensitivity to disease induced yield loss) at a particular growth stage. Paveley (1993) has integrated these factors for wheat by developing equations for each foliar disease to permit decisions on timing and dose to be made. The decision support system (DSS) Paveley has developed is called Integrated Disease Risk (IDR) Strategy. Values are inserted for each factor in the equation and a score determined. From that score the dose to be applied, which ranges from nothing to full, is determined.

This paper describes some of the background to the development of a parallel system for winter barley. *Rhynchosporium secalis* (leaf blotch) will be used to illustrate how the system is being developed.

FACTORS IN INTEGRATED DISEASE RISK

Diseases

Winter barley can be infected by a range of foliar diseases. The most important are mildew (*Erysiphe graminis*), Rhynchosporium leaf blotch (*Rhynchosporium secalis*), brown rust (*Puccinia hordei*) and net blotch (*Pyrenophora teres*). Knowledge of the biology of each pathogen provides information as to when disease is likely to develop and when control is likely to be required. Thus for *R. secalis*, most yield loss occurs when the two last formed leaves become infected (Chiarappa, 1971). The component of yield most affected is seed weight. Clearly, prevention of infection of the top two leaves is crucial to minimise yield loss. However, since the most effective fungicides provide only 60 to 80% control when the inoculum potential is high, fungicide use earlier in crop development to delay epidemic development is vital to long term control.

The rate of epidemic development for polycyclic diseases is driven by the initial inoculum and other factors that influence the epidemic. Of these other factors infection frequency, latent period and sporulation are largely determined by the resistance of the variety. IDR incorporates a value for host resistance in the equation for each disease. The remaining factor that affects epidemic development is spore dispersal efficiency. This is driven by weather factors which are also accounted for in the IDR equation.

Inoculum

If a DSS is to be used on farm it must involve a straightforward assessment of inoculum. Measuring spore production is impractical. Assessment of leaf tissue area infected by a particular disease is widely used as a measure of disease in research but on a farm level could result in large variation from the actual infection due to the subjectivity of the assessment method. Provided that correct identification is possible, the most unambiguous way to record disease is on a presence or absence basis. On the premise that the greater the degree of infection, the higher up the plant disease will occur, measuring presence or absence on a critical leaf layer is an objective way to measure inoculum provided the diseases concerned do not have long latent periods.

In order to determine a value for the inoculum factor in each IDR equation the user is asked to identify one of four levels of infection on a critical leaf layer. A value is assigned according to the level, as shown for *R. secalis* in Table 1. The critical leaf layer is the third top fully expanded leaf at the time of assessment until ear emergence when the second top leaf is considered.

TABLE 1. Values for different inoculum levels of *R. secalis*

Value	Level of infection
0	No leaf blotch on critical leaf layer and no obvious Rhynchosporium on plants
1	<10% leaves on critical leaf layer with at least one lesion or no infection on critical leaf layer but some leaf blotch detected on plants
2	10-25% leaves on critical leaf layer with at least one lesion of leaf blotch
3	>25% leaves on critical layer with leaf blotch and also detected on leaves above

Weather

Until the advent of on-farm weather stations and sufficient knowledge relating disease epidemiology to crop micro-climate, the integration of complex weather criteria into a DSS is unlikely. The prototype IDR for winter barley uses simplified criteria based on basic weather parameters that can be measured easily on-farm.

Few attempts to link climatic conditions to infection and development of *R. secalis* have been made. One of the earliest (Ryan & Clare, 1975) determined the relationship of the period of leaf wetness and temperature with infection. This relationship has been adapted in the UK to identify 'Rhynchosporium risk periods' using the duration of high humidity in met screens 2m above the ground following rainfall to determine the length of leaf wetness and the average temperature over the period of leaf wetness (Polley & Clarkson, 1978). In studies on spring barley Wale (1983) found that the best relationship between Rhynchosporium risk periods and the disease progress came from accumulating consecutive periods. On farm, most growers can only record daily rainfall and daily maximum and minimum temperatures. Whilst a much greater level of sophistication is possible, the relationship between weather and epidemiology of most barley diseases remains unclear.

For *R. secalis*, the prototype IDR system utilises the criteria used in PC-Plant Protection, a Danish DSS (Murali, 1991). This simply utilises the number of days in the previous 14 when there was rainfall of 1mm or more. Values for the weather factor in the IDR equation for Rhynchosporium are determined as shown in Table 2.

TABLE 2. Values for the *R. secalis* weather factor

Value	Weather conditions in last 14 days
1	Unfavourable - 1 day or less with 1.0 mm or more of rain
2	Average - not falling into favourable or unfavourable categories
3	Favourable - 5 or more days with 1.0 mm or more of rain

Varietal disease resistance

Disease resistance ratings for recommended cereal varieties are published annually (e.g. Anon.,1994 ; Anon., 1995). These ratings relate to the average infection on plots not receiving any fungicide in variety trials around the UK. They are a mean of three seasons trials. For certain diseases account is also taken of polytunnel tests where specific races of pathogen are screened against the same varieties as grown in variety field trials. Disease resistance ratings are an indicator of disease risk. They describe in a single figure the likely severity of infection when conditions favour disease development and compatible races of the pathogen are present.

Whilst the resistance rating for each disease is a crucial part of a risk assessment system, potential errors should be borne in mind. Firstly, the rating is a three year average. If there has been a change in the pattern of races over the seasons and virulence has increased, by using a three year average, the extent of the change in susceptibility may not be apparent from the rating. Secondly, for certain obligate pathogens, such as *Erisyphe graminis*, where resistance is controlled by a few major genes, the development of a new virulent race able to overcome resistance genes may invalidate the resistance rating. Thirdly, races are known to vary in different localities often in relation to the varieties grown in that region. This is not apparent from a single figure for resistance for the UK. Indications of changes in the virulence of pathogens in localities or over time may be indicated in pen notes for varieties in recommended lists.

Where a highly susceptible variety is grown the assumption that disease will automatically develop should be avoided. Without sufficient inoculum and suitable climatic conditions, even a susceptible variety will remain uninfected. This confirms the importance of integrating all major factors influencing disease in a risk assessment. In the prototype IDR the published resistance ratings are used to determine values which are inserted into the IDR equation for each disease (Table 3).

TABLE 3. Values for variety disease resistance ratings

Value	Disease resistance rating
0	9
1	8
2	7
3	6
4	5
5	4
6	3 or 2 or 1

Crop sensitivity

This factor is perhaps the most understudied component of this prototype system. For each disease the extent of potential yield loss will vary at different stages of growth. In winter barley, it is generally accepted that the greatest and most consistent yield response to fungicide occurs around the first node stage - GS 31 (Zadoks et al, 1974). A further important, but less consistent timing, is at flag leaf emergence (GS 37-49).

Responses to treatment at different times of fungicide application have been evaluated in different ways. For example, in a series of trials in north-east Scotland, Wale (1987) used programmes of fungicides with different combinations of four timings: early spring (end of tillering to pseudostem erect (GS 30), first node (GS 31), flag leaf emerged (GS 39-49) and ear emergence to end of flowering (GS 51-69). By subtraction it was possible to determine the response to each timing and an average response determined over the series of trials. The average responses and percent of occasions when the responses were cost effective are shown in Table 4.

Mildew and Rhynchosporium were the predominant diseases in this series of trials. For other diseases the response to timings are likely to be different. For example *Puccinia hordei* is likely to cause greater yield loss after ear emergence than other pathogens as it is capable of infecting awns.

TABLE 4. Yield response (t/ha) for different timings of fungicide application in winter barley and percentage of occasions cost effective

Timing	Yield response (% occasions cost effective)	
	Sown before 21 Sept	Sown after 21 Sept
Early spring	0.31 (80)	-0.36 (0)
	All sowing dates	
GS 31	0.65 (100)	
GS 39-49	0.69 (85)	
GS 51-69	-0.04 (29)	

Other trials have utilised 'wave' designs where single fungicide applications targeted at a single disease are applied at progressively later times. In such trials the optimum timing for yield response usually coincided with the optimum timing for disease control. The drawback of these experiments is that in practice more than one disease is usually present and the optimum time for one may not be optimum for the other.

In the prototype IDR system, for each disease, values are ascribed according to the potential relative yield loss at each timing. For Rhynchosporium the values are shown in Table 5.

TABLE 5. Values for *R. secalis* crop sensitivity

Value	Crop growth stage
0.75	up to GS 30
2.0	GS 31 to GS 37
3.0	GS 39 to GS 49
1.0	GS 51 onwards

IDR EQUATIONS

In developing IDR equations for each disease, the format developed by Paveley (1993) has been adopted. The equations have been formulated using knowledge obtained from field and trial experience. The equations are open to modification as more experience is gained. The equation for Rhynchosporium is:

IDR score = (A + 2B + C) x D

Values are inserted for inoculum (A), weather (B), variety disease resistance (C) and crop sensitivity (D).

The scores for each disease are then translated into a fungicide dose. The relevent doses for Rhynchosporium are shown in table 6. Doses relate to a specific broad spectrum mixture of a triazole and a morpholine fungicide. The table uses fungicide increments of a quarter dose but apart from a quarter dose as the minimum, there is no reason why dose should not be continuous in relation to the IDR score. In constructing the table, accommodation is made for two considerations. Firstly that control of *R. secalis* is unlikely to be complete and secondly that the dose selected is appropriate to provide sufficient disease control for the most cost effective yield response. A higher dose might give a greater degree of disease control but less profitably.

TABLE 6. Fungicides doses relating to scores derived from the IDR equation for *R. secalis*

Score	Fungicide dose
0 - 8.0	No fungicide
8.1 - 16.0	1/4 dose
16.1 - 24.0	1/2 dose
24.1 - 34.0	3/4 dose
> 34.1	Full dose

The decision to apply a fungicide will relate to when a previous application was made. In this prototype IDR it is assumed that no fungicide is required within three weeks of an earlier application

FUNGICIDE CHOICE

The activity of fungicides against foliar diseases of barley varies greatly. Relative performance at doses below the full recommended dose is scantily understood. Part of a current Home-grown Cereals Authority project on Appropriate Fungicide Doses for Winter Barley is determining relative dose response curves for many of the commonly used fungicides. This information is vital if IDR scores are to be translated in dose recommendations for a range of fungicide options. Ultimately the fungicide cost needs to be included to determine the most cost effective treatment.

RESULTS FROM A FIELD TRIAL

In a winter barley fungicide trial with the variety Pastoral, four treatments were compared in a randomised block design with three replicates. A 'full dose' programme was compared to an untreated control and programmes of fungicides applied at the same timings as the full dose programme but with fungicide dose decisions based on IDR or PC Plant Protection. The same triazole and morpholine fungicide mixture was used throughout. Rhynchosporium was present early in the spring and developed rapidly in cool, wet conditions.

It was the primary disease throughout the spring and summer. Mildew and net blotch were present but at low levels and spraying for these diseases was never triggered in the IDR equations. The trial is due to be harvested in August 1995 but disease assessments are shown in Table 7. The IDR treatments kept Rhynchosporium levels close to that of the full dose programme, but this was achieved using a half dose equivalent less fungicide.

TABLE 7. Comparison of fungicide programmes in which fungicide dose was determined using IDR or PC Plant Protection with a full dose programme and an untreated control. Variety Pastoral. Tillycorthie, Grampian. 1994/5.

Date & GS	22/3/95 GS 25			29/4/95 GS 32			24/5/95 GS 49		16/6/95 GS 69
Treat	%I	Dose appl.	%S	%I	Dose appl.	%S	%I	Dose appl.	%S
UT	88	0	15.9	98	0	34.1	100	0	47.3
Full	88	0.5	2.0	44	1.0	1.5	29	1.0	2.7
IDR	88	0.25	5.3	62	0.75	3.7	78	1.0	2.3
PC	88	0	18.0	95	0.75	8.4	82	0.9	9.1
S.E.D.			1.57			1.88			4.61

All assessments relate to the third top leaf at each growth stage
UT = untreated control, Full = Full doses applied at GS 32 and GS 49 and a half dose at GS 25. IDR = Integrated disease risk strategy, PC = PC Plant Protection.
%I = % incidence, %S = % leaf area infected. Sen. = Senescent

Experience using IDR equations for determining dose has been encouraging. The system has been relatively straightforward to use and the same conclusions on the appropriate dose to use have been reached by different assessors. Several seasons of trials are required to test the system, identify any weaknesses and, if required, modify the equations. There is no reason why additional factors to the four used could not be incorporated into the equation if more precision is required. However, it is unlikely that precision in determining the fungicide dose at any particular timing will be feasible unless detailed monitoring of the crop, disease and weather are possible. This IDR system is not designed to be precise but rather to give guidance and to present a more rational approach to determining dose. Inevitably, a small degree of insurance is built into the system to cover for unforeseen eventualities.

Rational approaches, such as IDR, to determining whether a fungicide is necessary and if so what dose should be applied will be crucial if farmers are to remain competitive when cereal prices within the EU fall to that of world prices. A system such as IDR also lends itself to incorporation into computerised DSS's which are likely to become important tools in the farm office in the future.

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