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Estimating Yield Loss from Light Leaf Spot (*Pyrenopeziza brassicae*) on Winter Oilseed Rape

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INTRODUCTION

Light leaf spot (*Pyrenopeziza brassicae*) has frequently occurred, sometimes as severe epidemics, on winter oilseed rape in the UK in the period since 1974 (Gladders, Fitt & Welham, 1995). Fungicides are currently an important and effective method for controlling light leaf spot and give good yield responses (Sansford, Fitt, Lockley & Sutherland, 1996). To ensure that fungicides are applied only to crops in which the severity of the epidemic warrants their use, not only disease forecasting (Gladders *et al.*, 1995) but also yield loss assessment (Sansford *et al.*, 1996) are essential. This report discusses work to compare different models for describing the relationship between yield and the severity of light leaf spot epidemics and to develop a simple method for predicting yield loss caused by the disease.

MATERIALS AND METHODS

Field experiments. The data selected for use in investigating these relationships were from field experiments in Scotland, in which epidemics of light leaf spot developed but other diseases did not. These field experiments were at Foveran in 1991/92, Pettymuick in 1992/93 and Udny Station in 1993/94, with the winter oilseed rape cultivar Envol (Sansford, Fitt, Gladders & Sutherland,1995; Sansford *et al.* 1996). There were 22 fungicide treatments, with different numbers and timings of a fungicide mixture applied to different plots to generate different disease epidemic patterns. At approximately monthly intervals, samples of ten plants were taken from selected plots and incubated at 15°C for 24 h before disease assessment. Growth stages (GS) of plants were recorded at each sampling date. Light leaf spot was recorded as percentage of plants affected (incidence), or the percentage of the area affected (severity) on leaves, stems and pods during the season. A disease index was calculated as the product of light leaf spot incidence and light leaf spot severity (index = incidence x severity).

Light leaf spot developed more severely on leaves in 1992/93, when disease incidence reached 100% by March, than in the other two seasons, when disease incidence did not reach 100% before June (Sansford *et al.*, 1996). Light leaf spot development on stems and pods occurred earlier and more severely in 1991/92 than in the other seasons. There was no light leaf spot on pods in 1993/94.

Data analyses and models applied. Simple and multiple regression analyses were applied by using the statistical software package Genstat (Lane & Payne, 1996). A Single Point (SP) model, a Multiple Point (MP) model and an Area Under Disease Progress Curve (AUDPC) model were used to analyse the relationship between yield decrease and light leaf spot development.

RESULTS

Single point models. Disease intensity (incidence or severity) at each growth stage (GS) / sampling date from the appearance of the first true leaf (GS 1.08/1.09 / early December) to pod development (GS 5.7 / mid-June) was related separately to final seed yield (y) at harvest in the three seasons. Regression analyses were done for yield (y) on disease incidence (x) or disease index (z) on leaves (d.f. = 36 in 1991/92, d.f. = 42 in 1992/93 and d.f. = 16 in 1993/94). The results showed that the percentage of the variance accounted for by models for yield on disease incidence or disease index generally had similar patterns with time during the season, except for the model on incidence after the appearance of the second true leaf (GS 1.12 / mid-February) in 1992/93. The regression on disease incidence just before flowering (GS 3.3 / early April) accounted for a greater percentage of the variance than regressions on disease incidence at other growth stages (1-39% in 1991/92; 25-43% in 1992/93;13-21% in 1993/94). At GS 3.3, the equations were:

1991/92 : $y = 4.42 - 0.013x$ ($r^2 = 50.3$; s.e. = 0.49)
1992/93 : $y = 4.57 - 0.018x$ ($r^2 = 47.4$; s.e. = 0.49)
1993/94 : $y = 4.46 - 0.0087x$ ($r^2 = 38.1$; s.e. = 0.29)
(y = yield in t/ha; x = % plants with light leaf spot at GS 3.3)

Regressions of yield on disease index accounted for similar percentage of the variance to those on incidence, except in 1992/93 at early flowering (GS 4.0 / early May) when the regression on incidence accounted for a smaller percentage of the variance:

1992/93 : $y = 3.77 - 0.104z_2$ ($r^2 = 62.0$; s.e. = 0.41)
(y = yield in t/ha; z_2 = light leaf spot index at GS 4.0)

Multiple point models. Multiple regression analysis was applied to yield on disease index at GS 3.3 and GS 4.0, the two stages for which regression of yield against disease incidence accounted for the greatest percentage of the variance in the single point models:

1991/92 : $y = 4.40 - 0.628z_1 - 0.071z_2$ ($r^2 = 46.2$; s.e. = 0.50)
1992/93 : $y = 3.81 - 0.020z_1 - 0.079z_2$ ($r^2 = 72.9$; s.e. = 0.35)
1993/94 : $y = 4.43 - 0.031z_1 - 0.219z_2$ ($r^2 = 31.7$; s.e. = 0.30)
(y = yield in t/ha; z_1= light leaf spot index at GS 3.3; z_2 = index at GS 4.0)

AUDPC models. AUDPCs for leaves for the three seasons were calculated from values of the disease index on leaves during the season. Yield was regressed on the AUDPC for disease index in each season and the following models were derived :

1991/92 : $y = 4.27 - 0.0080z_a$ ($r^2 = 40.6$; s.e. = 0.55)
1992/93 : $y = 3.68 - 0.00065z_a$ ($r^2 = 60.9$; s.e. = 0.42)
1993/94 : $y = 4.52 - 0.0019z_a$ ($r^2 = 44.9$; s.e. = 0.30)
(y = yield in t/ha; z_a = AUDPC of disease index)

Simple model for predicting yield loss. A simple model for predicting yield loss from disease incidence at GS 3.3 was selected because:

(1) Disease incidence is easier to assess than disease severity or disease index;
(2) Disease incidence can be assessed or forecast at an earlier stage in the season than can disease severity or disease index;
(3)The SP models based on disease incidence at GS3.3 were as accurate in explaining yield variation as MP or AUDPC models.

Data from the experiments in the three seasons were treated as non-replicates and combined together (d.f. = 84). Yield loss (yl) was calculated separately for each season using the estimated yield when disease incidence was zero as the maximum yield (y_0):

$$yl = y_0 - y_i$$

(yl = yield loss in t/ha; y_0 = maximum yield at zero disease incidence; y_i = yield at disease incidence x_i)

Disease incidence for the three seasons was regressed against yield loss to derive a simple model for forecasting yield loss :

$$yl = 0.017\,x_i - 0.037 \qquad (r^2 = 68.4;\ \text{s.e.} = 0.47)$$

DISCUSSION

These analyses suggest that it is possible to predict yield loss with a SP model based on light leaf spot incidence on winter oilseed rape at GS 3.3 in early April, in seasons like 1991/92 and 1993/94 when light leaf spot incidence did not reach 100% before the end of June. This may have been the optimum growth stage for prediction of yield loss because the disease incidence at GS 3.3 reflected the damage done by the disease over the winter period. Assessments later than GS 3.3 may have been less accurate for yield loss prediction because they were affected by the natural loss of leaves through senescence which occurs in the spring.

In seasons like 1992/93, when the light leaf spot epidemic was more severe and disease incidence reached 100% in March, the simple SP model based on disease incidence was less accurate than more complex models. For example, the SP model based on disease index, which incorporated an assessment of disease severity, gave a more accurate prediction of yield loss than the SP model based on incidence in that season, as did the MP and AUDPC models, which incorporated measurements of epidemic development in time. This phenomena is similar to that observed with polycyclic diseases on cereals, such as powdery mildew (Zaharieva *et al.*,1984).

However, the SP model based on incidence at GS 3.3 which used the data from all three seasons was as accurate in predicting yield loss as the MP and AUDPC models for 1992/93 alone. This model suggested that there would be a decrease in yield of 0.017 t/ha for each 1% increase in the percentage of plants affected by light leaf spot at GS 3.3. Such a SP model based on incidence has the advantage over the SP models based on disease index or the MP and AUDPC models that it is much easier to use in practice. Disease severity is much more difficult to measure than disease incidence and models which require complex calculations are less likely to be acceptable to growers. Nevertheless, further work to validate this model, using independent light leaf spot data sets from different sites and cultivars, and to establish clearly the conditions under which it is appropriate to use the model, is essential before it can be applied in practice. It is likely that it cannot be applied effectively in seasons when severe epidemics cause death of large number of plants on the winter (these dead plants would not be included on the assessment at GS 3.i) or when severe epidemics occur on pods later in the season. Furthermore, it is necessary to take the first decisions about the application of sprays against light leaf spot in the autumn if control is to be effective when epidemics are severe. Therefore, it will be necessary to examine the relationships between light leaf spot development in the autumn and disease incidence at GS 3.3 to establish disease thresholds for fungicide applications in autumn, even if accurate predictions of yield loss cannot be made in the autumn.

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