SUMMARY

Leaf stripe caused by *Pyrenophora graminea* has been the major yield-reducing factor for barley production during the last decade. In this study, the relationship between incidence (I; proportion of diseased plants) and severity (S; proportion of infected leaf area per plant) for leaf stripe of barley was investigated. Disease assessments were made visually at multiple sample sites in artificially and naturally inoculated research and production fields during four growing seasons. Significant differences (P = 0.05) in mean I and S values were found among cultivars, with values being consistently higher in the susceptible ones. However, leaf stripe severity increased linearly as incidence increased. The slopes and intercepts of the I–S relationship were consistent over the four growing seasons. The information obtained from this study is valuable for leaf stripe assessment which can substantially reduce the work load in disease quantification in field surveys and enable to select the resistant cultivars early in breeding programme.

**Key words:** *Pyrenophora graminea*, leaf stripe, barley, incidence, severity.

Leaf stripe, caused by *Pyrenophora graminea* (anamorph, *Drechslera graminea*), is an economically important seed-borne disease of barley found worldwide. In susceptible plants, the disease can result in severe stunting, premature death, and complete loss of grain (Tekauz and Chiko, 1980). Arabi et al. (2004) reported that leaf stripe was responsible for an annual yield reduction of 73% in highly susceptible barley varieties in Syria. The economic damage caused by leaf stripe can be avoided by using fungicides or by planting resistant cultivars, with the latter option being the more economically and environmentally appropriate solution. Both incidence (proportion of plant units diseased) and severity (proportion of plant unit showing symptoms) are commonly used measures to estimate disease. Incidence is a binary measurement (Madden and Hughes, 1999), i.e. a measure of only one of two possible states, diseased or not diseased. Thus incidence is quicker and easier to measure than severity, and measures of incidence are often more accurate, precise, and reproducible than measures of severity (Campbell and Madden, 1990).

Assessment of leaf stripe severity under field conditions is tedious and time-consuming and may be prone to bias and experimental error (Tekauz and Chiko, 1980). Despite the drawbacks, however, severity is often considered a more important and useful measure of disease intensity than incidence for the evaluation of yield loss and for determining the effectiveness of disease management strategies (Campbell and Madden, 1990). Since measures of incidence are more easily acquired and more reliable than measures of severity, and since severity is more useful than incidence for certain objectives, a quantitative relationship between incidence and severity would greatly facilitate the evaluation of disease intensity when accurate assessments of severity are not available or possible (Seem, 1984). In the present study, the I–S relationship of leaf stripe was investigated to explore the possibility of simplifying disease assessment.

Commercial barley fields and research plots were naturally infected with *P. graminea*, while disease-screening nurseries were infested artificially with the most virulent isolate (Sy3) of *P. graminea* in Syria (Arabi et al., 2002, 2004). In order to acquire data from leaf stripe epidemics of different intensity, two research plots and production fields were selected for leaf stripe assessment in Syria during four growing seasons. The ten barley cultivars used in this study were chosen for their wide genetic variability for leaf stripe reaction from highly susceptible to highly resistant (Table 1). The universal susceptible cultivar WI 2291 from Australia was included in each set as control.

Seeds were artificially inoculated with Sy3 following the procedure set out by Hammouda (1986). The experimental design was a randomized complete block design with three replicates. Plot area was 1 x 1 m with a 1 m buffer. Each plot consisted of 5 rows 25 cm apart with 50 seeds sown per row. Experimental design, cul-
cultural practices, inoculation methods, and mist irrigation were as previously described (Arabi et al., 2004). Weeds were controlled by pre- and post emergence herbicides as appropriate. Soil fertilizers were drilled before sowing at a rate of 50 kg/ha urea (46% N) and 27 kg/ha superphosphate (33% P).

In each field/plot, incidence and severity were estimated visually at several systematically selected sampling sites. Incidence (I) was recorded as the proportion of diseased plants (number of plants with nonzero severity divided by the total number of plants sampled). Severity (S) was recorded as infected leaf area per plant expressed as a proportion of the total area.

The data for I and S were analyzed by analysis of variance (Newman-keuls test), using the STAT-ITCF program (Anonymous, 1988). For all data, each pair of incidence and severity values from each sampling site was considered as an observation for data analysis. The data were edited to remove observations with no diseased plants (i.e., I = 0 and S = 0), since the I-S relationship is only defined when disease is present. The assumption of coincidence of the four regression lines for each year was tested using the ANOVA procedure implemented in the software package Statistica 6.1. Years were set as the categorical variable and coincidence was tested by simultaneously checking year’s effect combined with its interaction with the incidence.

Significant differences (P = 0.05) in mean I and S values were detected with values being consistently higher in the susceptible cultivars during the four growing seasons (Table 1). For data collected from all experiments, for a given value of disease incidence, a range of severity values was observed (Table 1). The data showed that the highest mean incidence and severity were recorded in cultivars WI 2291 and Arabi Abiad (I = S = 100), whereas the lowest was found in the resistant cultivars Banteng (I = S = 1).

The results show that leaf stripe severity increased linearly as incidence increased (Fig. 1). There was no difference in the slopes and intercepts of the I-S relationship in different years, as it was shown by the test of coincidence (F6, 32 = 1.16, P = 0.65). Subsequently, data from all years were pooled to calculate a single regression line. These findings are in agreement with the results of Paul et al. (2005) for Fusarium head blight on winter wheat. In some cases I = S for one or more observations such as in the susceptible cultivars WI2291 and Arabi Abiad (Table 1). This can be justified by the fact that when all plants in the sample are diseased, there is no longer any information on the magnitude of (mean) severity in relation to incidence, other than being larger than the (mean) severity when some plants are disease-free. In this extreme situation, severity and incidence are the same.

The differences in the means of increase in incidence and severity have been attributed to the occurrence of two distinct types of infection, allo- and auto-infection.

**Table 1.** Mean leaf stripe disease incidence (I) and severity (S) in 10 barley cultivars inoculated with isolate Sy3 of *Pyrenophora graminea* under field conditions during four growing seasons.

<table>
<thead>
<tr>
<th>S</th>
<th>I</th>
<th>Source</th>
<th>Cultivar</th>
</tr>
</thead>
<tbody>
<tr>
<td>100a</td>
<td>100a</td>
<td>Australia</td>
<td>WI2291</td>
</tr>
<tr>
<td>100a</td>
<td>100a</td>
<td>Syria</td>
<td>Arabi Abiad</td>
</tr>
<tr>
<td>90.7b</td>
<td>95.0b</td>
<td>USA</td>
<td>Arrivate</td>
</tr>
<tr>
<td>78.1c</td>
<td>82.3c</td>
<td>Syria</td>
<td>Furat1</td>
</tr>
<tr>
<td>60.3d</td>
<td>61.7d</td>
<td>England</td>
<td>Golf</td>
</tr>
<tr>
<td>15.7e</td>
<td>21.7e</td>
<td>France</td>
<td>Thibaut</td>
</tr>
<tr>
<td>16.0e</td>
<td>20.0e</td>
<td>England</td>
<td>Igri</td>
</tr>
<tr>
<td>13.7e</td>
<td>16.0f</td>
<td>Pakistan</td>
<td>PK30-126</td>
</tr>
<tr>
<td>13.0e</td>
<td>14.0f</td>
<td>Ethiopia</td>
<td>CI-5791</td>
</tr>
<tr>
<td>1.0f</td>
<td>1.1g</td>
<td>Germany</td>
<td>Banteng</td>
</tr>
</tbody>
</table>

Values followed by different letters within columns are significantly different at P = 0.05 according to Newman-keuls test.
for polycyclic diseases (Seem, 1984). An increase in incidence results from allo-infection (spread among plant units – plants), whereas an increase in mean severity within a sampling unit results from both allo- and auto-infection (spread within infected plant units – leaves). Using simulation models, Willocquet and Savary (2004) demonstrated that the time taken for maximum disease incidence (I = 100) to occur decreases with increasing allo-infection. In the case of leaf stripe, which normally functions as a monocyclic disease, the infection of new disease-free plants from primary inoculum (analogous to allo-infection) was probably higher than the spread within infected plants (analogous to auto-infection).

Pataky and Headrick (1988) reported that the relationship between incidence and severity for common rust of sweet corn varied with distance from a source of inoculum. Because leaf stripe is a monocyclic disease, inoculum density certainly will influence incidence level.

The cultivars planted during the four growing seasons of this study varied in resistance to leaf stripe. However, cultivars that are resistant to leaf stripe may in fact have different resistance responses to the spread of the fungus within the infected plants, hence a wide range of severity values may be observed across cultivars for any given incidence value. McRoberts et al. (2003) reported that incidence–severity analysis is directly useful in evaluating resistance response. In particular, the incidence–severity relationship could be used to draw conclusions about the relative rate of disease increase among cultivars with different levels of resistance.

It appears that neither differences in weather conditions during the four growing seasons, nor geographical locations resulted in any different patterns in the I-S relationship. In addition, in the present study, the number of plants sampled and the small distance among locations did not affect I-S relationship either. It is noteworthy that in the I-S relationships among locations have been reported for powdery mildew of apple (Seem and Gilpatrick, 1980).

Clearly, this study shows strong correlations between leaf stripe incidence and severity in barley which was consistent among seasons and locations. However, characterizing the functional relationship between incidence and severity is still critically important, because through this relationship researchers can identify the cultivars with unusually large or small severities for a given incidence (McRoberts et al., 2003), or through covariance analysis (when there are several pairs of I-S points for each cultivar), identify cultivars with an unusual I-S relationship compared with others. Moreover, in breeding programs where potentially thousands of early-generation lines are assessed for leaf stripe reaction, the estimation of incidence, and not severity, would save considerable resources.

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REFERENCES


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