Guidelines for Use of Foliar Sprays to Control Stripe Rust of Wheat in Australia

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ABSTRACT

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Guidelines have been developed that advise Australian farmers when to spray wheat (*Triticum aestivum*) crops to control stripe rust (*Puccinia striiformis*). These guidelines state that crops should be sprayed with a suitable fungicide when 1% of the leaf area is affected by stripe rust (equivalent to 35–40 affected leaves per 100 examined) provided the predicted yield loss is sufficient to make spraying economical. Prediction of yield loss is based on the apparent infection rate in the cultivar and on the time in the growing season when 1% of the leaf area is affected by stripe rust.

Stripe rust of wheat (*Triticum aestivum* L.), caused by *Puccinia striiformis* West., was first observed in Australia in 1979. Farmers attempted to control the disease with foliar sprays of triadimefon (Bayleton 25% EC) in 1980 and 1981, but yield responses were variable, especially in 1980. One reason for the poor response was that farmers delayed spraying until the stripe rust epidemic was well established; rust often covered more than 10–15% of the leaf area before the fungicide was applied. Observations from separate spray experiments in 1980 showed that yield increases of 16.5, 14.6, and 4.2% were obtained when stripe rust covered 2.5, 6.7, and 19.6% of the leaf area, respectively, at spraying (1,2; J. S. Brown, *unpublished*). The United Kingdom's Agricultural Development and Advisory Service guidelines for chemical control of stripe rust of wheat also recognize the need to spray early in the development of the epidemic and recommend that, for best effect, fungicides should be applied before the disease covers 5% of the area of the top two leaves, irrespective of growth stage (7).

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This paper develops guidelines for using fungicides to control stripe rust of wheat in Australia from a consideration of the relationship between the percentage of leaf area affected (percent attack) at soft dough growth stage and yield loss, spray timing, detection of low percent attack, prediction of yield loss on the basis of onset and anticipated rate of development of the epidemic, and yield loss for economic spraying. Practical application of the guidelines is also considered.

GUIDELINES

Relationship between percent attack and yield loss. Researchers have reported numerous methods for estimating yield loss from measures of the disease epidemic such as disease severity at one or more growth stages and area under the disease progress curve (3,4,6). We developed a relationship between stripe rust percent attack (PA) and grain yield loss (YL) by field experiments at Dooen, Victoria, in 1979 and 1980. Ten wheat cultivars, varying in their susceptibility to stripe rust, were grown and YL was estimated by comparing disease-free plots (sprayed one to three times with triadimefon) with plots in which the disease developed naturally.

We statistically analyzed the data by

the least-squares method and found that the relationship between PA at the soft dough growth stage (GS 85) (9) and percent YL was described by the equation:

$$YL = -0.348 - 0.375\,PA + 6.034\,(PA)^{1/2}PA \quad (r = 0.893,\ P \leqslant 0.001). \qquad (1)$$

Spray timing. Successful economic control of pathogens with chemicals requires that the fungicide be applied very early in the development of the epidemic (2,3; J. S. Brown, *unpublished*). In Australia, where average wheat yields are relatively low (1.5–2.5 t/ha), it is not economical to apply more than one spray. This, however, should be sufficient because stripe rust epidemics begin between stem elongation (GS 33) and anthesis (GS 60) and because a single spray of a systemic fungicide gives control for 4–6 wk (1,2). Thus, the main constraint to spraying early is detection of the disease early enough in the epidemic to derive maximum economic benefit.

Detection of low PA. During the early phase of epidemics of powdery mildew (*Erysiphe graminis* DC. f. sp. *tritici* Marchal) and leaf rust (*Puccinia recondita* f. sp. *tritici* Rob. ex Desm.) of wheat, percent leaf area affected can be determined accurately from percent affected leaves (5). Because percent affected leaves is easier to determine than percent leaf area affected, we investigated the relationship between the two by monitoring stripe rust epidemics in commercial crops. At regular intervals, we measured stripe rust PA and percent affected leaves (disease incidence, DI) in three wheat cultivars growing at each of three locations in 1980 and 1981. We statistically analyzed the data with a stepwise regression algorithm operating at the 5% level and found that, for PA <3, the relationship between PA and DI was described by the equation:

$$\log_e PA = 1.177 \log_e DI - 4.316 \quad (r = 0.934,\ P \leqslant 0.001). \qquad (2)$$

Thus, PA 1 corresponds to an average of 35–40 affected leaves per 100 examined; therefore it should be easy for farmers to detect this level of disease.

Prediction of YL. For a wheat crop affected by stripe rust, YL can be predicted from equation 1 if PA at GS 85 can be predicted. This depends on the time available for and rate of epidemic development. The time available for epidemic development (Δt) is the days from PA 1 to GS 85. The former date is determined by monitoring disease development in the crop and the latter date is estimated from crop development information for the region. The apparent infection rate (r) is a measure of the rate of epidemic development (8). We have determined r for the cultivars commonly grown in Victoria (Table 1) by monitoring epidemics of stripe rust in commercial crops growing at each of one to three locations in each of 1–3 yr. Vanderplank (8) has related r to PA and time by the equation:

$$r = [1/(t_2 - t_1)] \log_e [x_2(1 - x_1)] / [x_1(1 - x_2)], \qquad (3)$$

where x_1 = PA (proportion) at time t_1 and x_2 = PA at time t_2.

Table 1. Advice on spraying that would have been given to wheat growers in the Wimmera region of Victoria, Australia, if the guidelines had been used in 1979–1981

Cultivar	Stripe rust reaction	Apparent infection rate (r)[v]	Epidemic development time (Δt)[w] 1979: 27	1980: 47	1981: 24
Kalkee	Susceptible	0.148 (±0.051)[x]	Sp[y]	Sp	Sp
Katyil	Susceptible	0.146 (±0.056)	Sp	Sp	Sp
Zenith	Susceptible	0.138 (±0.044)	Sp	Sp	Sp
Kewell	Moderately susceptible	0.109 (±0.036)	Sp	Sp	Sp
Olympic	Moderately susceptible	0.073 (±0.021)	NSp	Sp	NSp
Condor	Resistant	0.037	NSp	NSp	NSp
Egret	Resistant[z]	0.033 (±0.013)	NSp	NSp	NSp
Egret	Susceptible[z]	0.143	Sp	Sp	Sp

[v] Calculated as the regression coefficient of logit PA (percent attack) on time.
[w] Days available for epidemic development, from PA 1 (1% of leaf area affected; equivalent to 35–40 affected leaves per 100 examined) to GS 85 (soft dough growth stage).
[x] Figures in parentheses are standard deviations of r over years; r for resistant Condor and susceptible Egret determined only in 1 yr.
[y] Sp = spraying advised; NSp = spraying not advised.
[z] Egret is mixed in its reaction to stripe rust.

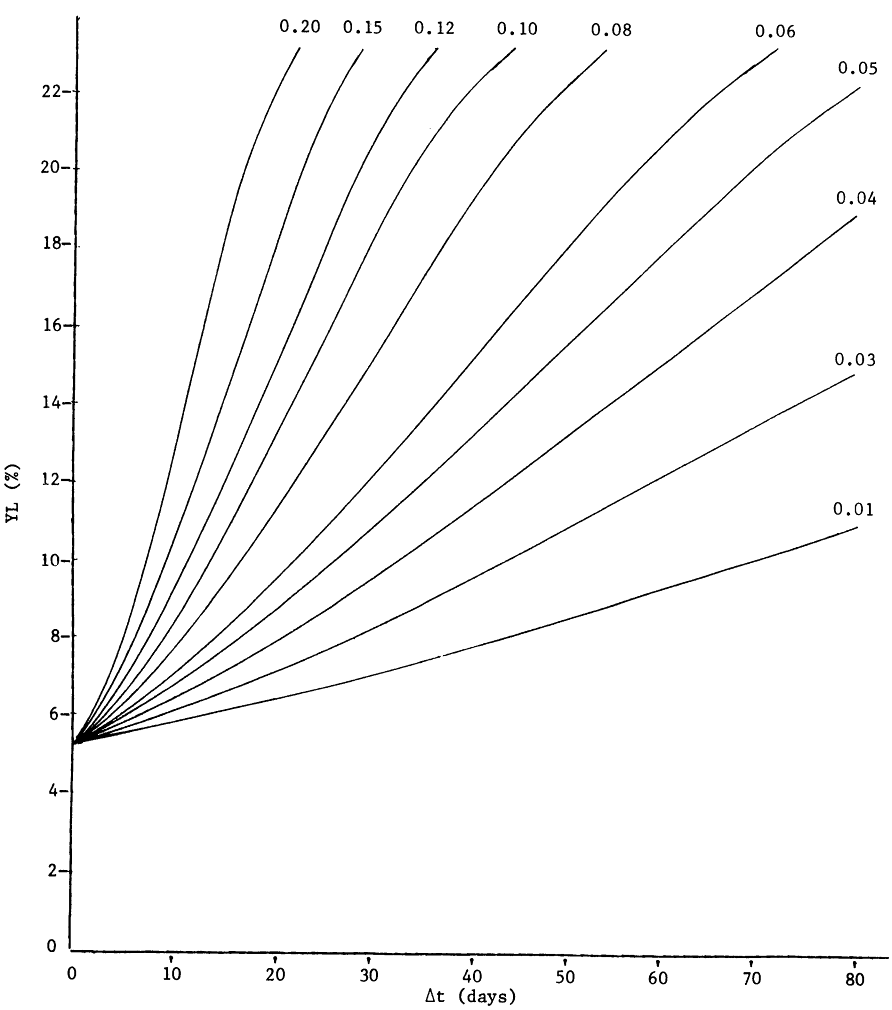

Fig. 1. Relationship between percentage of yield loss (YL) and epidemic development time (Δt) for different apparent infection rates (r) as indicated on curves. The curves were generated by substituting different values of r and Δt into the equation: $YL = -0.348 - 0.379\,PA + 6.034\,(PA)^{1/2}$, where $PA = [(0.01_e^{r\Delta t})/(0.99 + 0.01_e^{r\Delta t})]$ (PA = percent attack).

We rearranged equation 3 and substituted 1% for x_1 and Δt for $(t_2 - t_1)$ so that PA at GS 85 (x_2) can be predicted. By this rearrangement, equation 3 becomes:

$$x_2 = (0.01_e{}^{r\Delta t})/(0.99 + 0.01_e{}^{r\Delta t}). \quad (4)$$

By combining equations 1 and 4, we predicted YL for a number of combinations of Δt and r (Fig. 1).

Economic spraying. To justify spraying, the expected financial loss from stripe rust must be greater than the cost of the operation. This cost can be calculated from an estimate of the value of the crop (CV, \$/ha), the cost of fungicide (FC, product plus application), and the value of the 5.3% loss that cannot be recovered because spraying occurs at PA 1 (equation 1). Thus, for spraying to be economical, we calculate that:

$$\text{Predicted YL} > [(5.3\%\text{ of CV} + \text{FC})/\text{CV}] \times 100\%. \quad (5)$$

PRACTICAL IMPLEMENTATION

The guidelines advise farmers to spray at PA 1 if the expected YL is greater than the costs of spraying. Farmers are advised to monitor their crops by counting the number of infected leaves on 100 tillers along two diagonals of each field. The date at which DI reaches about 35 infected leaves per 100 examined is used to calculate Δt. This estimate of Δt, together with an estimate of r for the variety, is plotted in Figure 1 and the YL is predicted. If the requirements of equation 5 are met, spraying is worthwhile.

In the Wimmera region of Victoria where stripe rust epidemics have been severe, crop values were about \$300/ha and spraying with triadimefon cost about \$25/ha. The YL for economic spraying was therefore 13.6%. On this basis, we determined the advice that farmers would have received if the guidelines had been used in 1979–1981 (Table 1).

These guidelines can readily be adapted to other regions where stripe rust can be controlled by a single foliar spray. If basic phasic development data are available, Δt can be determined easily and accurately, and r does not need to be accurately measured: it is sufficient to be able to group cultivars into broad classes with similar r values. This information can be obtained by monitoring epidemics, and these data are available for many cultivars from cultivar evaluation experiments.

Until a generalized crop loss model for stripe rust of wheat is developed, however, the empirical crop loss relationship that is applicable in Victoria may need to be modified for each region. The guidelines assume that r is constant throughout the epidemic. This is the case for the cultivars studied in Victoria but may not be in other location-cultivar combinations. If the epidemiology of the pathogen and the reaction of the local cultivars is understood, however, the guidelines can be applied.

The guidelines we developed can be used to estimate the time in the growing season beyond which, if PA has not reached 1, spraying is not economical. For example, in Victoria this growth stage in stripe rust resistant cultivars (eg, Condor) is at midjointing, but it is at late boot stage in the moderately stripe rust resistant cv. Olympic, at the late heading stage in the moderately stripe rust susceptible cv. Kewell, and at anthesis in the stripe rust susceptible cv. Zenith.

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