FUNGICIDE CONTROL OF STRIPE RUST IN WHEAT: PROTECTION OR ERADICATION?

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ABSTRACT

A spring-sown field trial at Lincoln in the 2001/2002 growing season assessed the relative protectant and eradicator activity of the fungicides azoxystrobin and epoxiconazole, for control of wheat stripe rust caused by the fungus *Puccinia striiformis*. The fungicides were applied at different stages of a stripe rust epidemic, nil disease, trace of disease or moderate disease, on five wheat cultivars which differed in susceptibility to the disease. Disease severity and host reaction were also measured. The mean area under the disease progress curve (AUPDC) of flag leaves of the susceptible cultivar Tiritea was reduced by 65% after application of azoxystrobin, and by 37% after application of epoxiconazole. The AUDPC for the moderately susceptible cultivar Karamu was reduced by 41-50% by both of the fungicides. The more resistant cultivars, Impact, Sapphire and Otane, had very low AUDPCs and would probably not benefit from an application of fungicide to control stripe rust, unless the pathotype present was highly virulent against these cultivars. Depending on disease pressure, fungicides on susceptible cultivars should be applied at or near flag leaf emergence.

Keywords: *Puccinia striiformis*, stripe rust, wheat, azoxystrobin, epoxiconazole.

INTRODUCTION

Fungicides from different groups are registered for the control of wheat stripe rust in New Zealand. Protectant fungicides protect plants against pathogen propagules establishing infections, but are ineffective against established infections (Manners 1993). Eradicator fungicides enter plants, kill established infections and also stop existing latent (invisible) infections (Manners 1993). The comparative efficacy of fungicides depends partly on the crop growth stage and disease level at the time of application, and may not accurately reflect their relative protectant or eradicator activity.

An often-asked question is, 'When, in relation to crop growth stage and disease severity, should a fungicide be applied?' Resistance of the crop cultivar to the disease, as well as the type of fungicide used, are important factors that have to be considered. Inappropriate timing can have important consequences: too soon, and the protectant activity may have diminished before disease pressure is high; too late, and the eradicator and reach-back activity will be insufficient to control the disease epidemic. The fungicide must also offer protection for a reasonable length of time to make applications economic. Incorrect timing may also lead to poor apparent fungicide performance and excessive use of fungicides.

Our objectives were firstly to determine the relative protectant and eradicator activity of fungicides from two chemical groups against stripe rust of wheat, caused by the fungus *Puccinia striiformis* Westend. f.sp. *tritici*, and secondly to determine the consequences of applying fungicides at different stages of a stripe rust epidemic in cultivars differing in susceptibility to the disease.

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MATERIALS AND METHODS

A spring-sown field trial contained five wheat cultivars, Impact, Karamu, Otane, Sapphire and Tiritea, with different susceptibilities to stripe rust. There were two fungicides, azoxystrobin and epoxiconazole, applied at four timings, Nil, Protectant, Early eradicant and Eradicant. The trial was sown on 9 August 2001 at Lincoln, Canterbury, New Zealand. There were three replicates and 39 treatments with double replicates of Nil fungicide for each cultivar, laid out in a randomised block design. Some attempt was made to evenly distribute the cultivars and fungicide treatments across the rows and columns of plots. The trial was bordered on the west and east side by a 3 m wide buffer strip sown with a mixture of the cultivars Batten, Pegasus and Endeavour, to encourage development of *P. striiformis* pathotypes with matching virulence on these genes.

Plots (5 m by 1 m) were sprayed with tebuconazole (440 ml/ha, Folicur®) at the 2-3 leaf stage to delay the epidemic until stem elongation. Plants of cultivar Tiritea were grown in 10 cm pots in a glasshouse and were inoculated with a mixture of *P. striiformis* pathotypes virulent on the host genes *Yr6*, *Yr9* and *YrA* (these genes were present in the cultivars used in the trial). The profusely sporulating inoculated plants were transplanted into the field plots on 19 October 2001 when the plants in the experiment were at stem elongation. Prior to application of spray treatments, the youngest fully expanded leaf was labelled on 10 plants per plot to allow comparisons between leaves at a later stage and to identify leaves that received the fungicide treatment. The Protectant fungicide treatments, azoxystrobin (0.75 litres/ha Amistar®) or epoxiconazole (1 litre/ha Opus®), were applied 2 days before inoculation on 17 October 2001 at GS 31-32 (stem elongation). The Early eradicant treatments (same fungicides) were applied 12 days after inoculation (DAI) on 31 October 2001 at GS 39 (flag leaf emergence) when there was some disease on susceptible cultivars. The Eradicant treatments (same fungicides) were applied 40 DAI on 28 November 2001 at GS 61-65 (early to mid anthesis) when disease was well established on susceptible cultivars.

Disease assessments, number of sporulating and dead pustules, percentage of necrotic leaf area and percentage of leaf area infected, of labelled leaves and the ones that emerged later were carried out at regular intervals, five times for the Protectant treatments, seven times for the Early eradicant treatments and eight times for the Eradicant treatments. The protectant activity of the fungicides was determined by measuring time from inoculation until pustules from new infections appeared. The eradicant activity of the fungicides was determined by measuring the time until spore production of existing pustules ceased, time until pustule production of latent infections ceased, and host reaction (necrosis or chlorosis) when the fungus in the leaf died.

Data used here were from labelled leaves only. For the Nil treatment, the leaves used in the analysis corresponded with the leaves for each fungicide treatment. Day 0 (DAI) was set at 19 October 2001, the date of inoculation. The number of days until live and dead pustules or necrosis first appeared was calculated for each labelled leaf and the minimum day value for each plant was obtained. The mean number of days until a plant first showed necrosis or dead or live pustules for each plant were calculated using GenStat cross-tabulation. Statistical analysis was not possible on the mean number of days until live or dead pustules were recorded because of the unbalanced number of plants with pustules in each cultivar and treatment and the number of plants without pustules due to cultivar resistance or efficacy of the fungicide treatments. The AUDPCs were calculated as described in Viljanen-Rollinson & Cromey (1998) and analysed for the time of each fungicide application using REML (GenStat 5th edition).

RESULTS

The mean AUDPC data showed that there were no differences between the cultivars ($P>0.05$) or fungicides ($P>0.05$) when the fungicides were applied as Protectant treatments. When they were applied as Early eradicant treatment, there were statistically significant differences between cultivars ($P<0.001$), but not between treatments ($P>0.05$).

Mean AUDPCs for Early eradicator treatments of Impact, Sapphire and Otane were similar, but were less than mean AUDPC for Karamu, which was less than the mean AUDPC for Tiritea (Table 1). Application of fungicides did not affect the mean AUDPC for the resistant cultivars, but the mean AUDPC for Karamu was approximately halved after application of the fungicides. The mean AUDPC of Tiritea was reduced by almost 70% following the application of azoxystrobin, but epoxiconazole had no effect (Table 1).

When fungicides were applied as Eradicator treatments, there were statistically significant differences between cultivars ($P < 0.001$) and fungicide treatments ($P < 0.01$), and the cultivar $\times$ fungicide interaction was also statistically significant ($P < 0.01$). For Eradicator fungicide treatments, the mean AUDPCs for Impact, Sapphire and Otane did not differ from each other but were less than the mean AUDPC for Karamu. The mean AUDPC for cultivar Tiritea was the highest. The two fungicides reduced the mean AUDPC for Karamu almost equally (41-50%), but azoxystrobin reduced the mean AUDPC for Tiritea by 65% while epoxiconazole reduced it by 37% (Table 1).

TABLE 1: Mean areas under disease progress curves for different cultivars of wheat following different fungicide treatments.

Treatment	Impact	Karamu	Otane	Sapphire	Tiritea	Mean
Protectant						
- Nil	0.0	0.0	0.5	4.9	0.0	0.91
- Azoxystrobin	0.4	0.0	0.7	0.0	-	0.31
- Epoxiconazole	1.8	0.0	9.5	0.0	0.0	3.30
Early eradicator						
- Nil	2.2	540.8	4.2	0.7	1098.1	348.53
- Azoxystrobin	2.9	15.5	7.9	0.1	342.4	73.77
- Epoxiconazole	0.2	6.6	3.3	0.6	1076.7	217.49
Cultivar mean	1.8	187.6	15.5	0.2	844.2	
LSD ($P < 0.05$) = 322 (for comparing cultivar means)						
Eradicator						
- Nil	13.9	830.4	21.1	4.7	2374.4	694.91
- Azoxystrobin	12.0	487.8	48.5	17.9	833.4	279.93
- Epoxiconazole	15.7	417.8	41.8	1.3	1490.0	393.30
LSD ($P < 0.05$) = 579 (for comparing treatments), LSD ($P < 0.05$) = 575 (for comparing cultivars)						

The mean number of days after inoculation until live and dead pustules and necrosis were recorded are in Table 2. Few plants developed pustules (live or dead) following the Protectant treatment. No live pustules developed on cultivars Impact, Sapphire and Tiritea. On average, necrosis developed 27 DAI in Nil plots, excluding Tiritea which did not develop any necrosis (Table 2). Necrosis developed 36 DAI in plots treated with epoxiconazole and 39 DAI in plots treated with azoxystrobin (Table 2). Assessments of the Protectant fungicide treatment plots ceased 53 DAI because the tagged leaves had senesced.

Live pustules were recorded approximately 36 DAI for the Early eradicator treatments for both fungicides, while dead pustules were recorded on average 48 DAI, approximately 12 days after live pustules were recorded (Table 2). Cultivar Impact did not develop any live pustules and only a few dead ones. The mean number of days until necrosis was evident was on average over all cultivars approximately 33 DAI for azoxystrobin-treated plots, 36 DAI for epoxiconazole-treated plots and 37 DAI for untreated Nil plots (Table 2).

Live pustules were recorded on average 55 DAI on all cultivars treated with azoxystrobin applied as Eradicant treatment, 47 DAI treated with epoxiconazole and 44 DAI in Nil plots (Table 2). Dead pustules were recorded 54 DAI for both fungicide treatments and 53 DAI for Nil treatment. Necrosis was recorded 39 DAI in Nil plots, 46 DAI in plots treated with epoxiconazole and 53 DAI in plots treated with azoxystrobin (Table 2).

TABLE 2: Mean numbers of days after inoculation until live pustules, dead pustules and necrosis were recorded on leaves of different cultivars of wheat. The number of plants this figure was derived from is shown in parentheses.

Treatment	Live pustules	Dead pustules	Necrosis
Protectant			
- Nil	31.0 (1)	- (0)	27.0 (5)
- Azoxystrobin	53.0 (2)	- (0)	39.4 (5)
- Epoxiconazole	47.0 (2)	46.5 (4)	35.6 (11)
Early eradicant			
- Nil	40.3 (68)	51.0 (59)	37.3 (39)
- Azoxystrobin	35.8 (13)	48.2 (15)	32.7 (22)
- Epoxiconazole	36.0 (19)	48.3 (22)	35.6 (17)
Eradicant			
- Nil	43.9 (130)	52.6 (144)	39.2 (75)
- Azoxystrobin	54.5 (31)	53.7 (109)	53.3 (15)
- Epoxiconazole	47.2 (62)	54.4 (98)	46.2 (10)

DISCUSSION

The mean AUDPC results show that there was little benefit in applying fungicides as Protectant at GS 31-32 because very little stripe rust developed on the labelled leaves, even in susceptible cultivars, before the leaves senesced. Therefore, it was difficult to determine the efficacy of the Protectant treatment from the AUDPC, pustule number and necrosis data. However, in some years stripe rust can appear in the field very early, so wheat crops should be examined carefully and fungicide may have to be applied to susceptible cultivars earlier than is recommended here.

Azoxystrobin applied as Early eradicant appeared more effective than epoxiconazole in reducing the amount of disease on Tiritea. The disease pressure was greatest when the fungicides were applied as Eradicant, and consequently mean AUDPCs were high for Karamu and Tiritea. Tiritea is very susceptible to stripe rust and may require two fungicide applications for effective disease control through the whole growing season. Karamu, which contains the gene *YrA* for resistance to stripe rust, has again (Viljanen-Rollinson & Cromey 1998) proven to be very susceptible to the disease. This cultivar requires additional control, especially under high disease pressure. In this study, both fungicides applied as Eradicant achieved 41-50% reduction in the AUDPC for Karamu. The more resistant cultivars, Impact (contains the gene *Yr9* for resistance), Sapphire (gene *Yr6* and other unidentified genes) and Otane (gene *Yr18* and other unidentified genes), had very low AUDPCs, and would probably not benefit from an application of fungicide to control stripe rust unless the pathotype present in the field was highly virulent against the genes contained in these cultivars and the environmental conditions were highly conducive to the development of the pathogen. The pathogen causing stripe rust of wheat has been highly adaptable in New Zealand conditions and new pathotypes arise regularly due to mutation or importation. This demonstrates the importance of using diverse disease

resistance sources in breeding programmes to increase the durability of resistance to stripe rust.

Fungicide applications for stripe rust in wheat cultivars should be applied to susceptible cultivars before the disease becomes too severe. Depending on the disease pressure, in susceptible cultivars this should be carried out at or soon after flag leaf emergence (GS 39). In some cases, two or more fungicide applications are required. When disease pressure is high, an application carried out later, at early or mid anthesis, may be too late to adequately protect plants from infection. Hims & Cook (1991) found that application of fungicides between flag leaf emergence and early ear emergence (GS 39-55) was most effective against stripe rust development. They found that approximately 35% of leaf area was infected at GS 75 when stripe rust first appeared on leaves at GS 59.

It is not always appropriate to rely on the eradicant properties of fungicides, especially when disease pressure is high and the cultivar grown is very susceptible. Fungicide inputs must be based on knowledge of cultivar resistance, disease risk and pressure, influence of meteorological factors on disease development and sound knowledge of the protectant and eradicant properties of the fungicides used. Additional information on the effects of these treatments on final yield is required, as well as cost-benefit analyses of using various fungicides so that growers can maximise their returns. Additional information is also required on the range of fungicides that are available, new ones to the market as well as the more traditional chemicals. Furthermore, it may be possible to make savings by using reduced rates of fungicides instead of full rates, especially for cultivars with at least a degree of resistance to stripe rust. New research to predict disease risk under local conditions using different cultivars would be worthwhile.

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