RYEGRASS *(LOLIUM PERENNE)* SEED YIELD RESPONSE TO FUNGICIDES: A SUMMARY OF 12 YEARS OF FIELD RESEARCH

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ABSTRACT

A summary of seed yield data from 19 fungicide trials in perennial and hybrid ryegrass (*Lolium* spp.) seed crops conducted over a 12 year period is presented. Seed yields from the best fungicide treatments were increased on average by 25% in forage ryegrass (390 kg/ha) and 42% in turf ryegrass (580 kg/ha). Seed yield increases were associated with the control of stem rust and/or maintaining green leaf area during seed fill. In turf ryegrass (susceptible to stem rust) delaying the first fungicide application until stem rust appeared resulted in seed yields that were not different (P>0.05) from the untreated experimental controls, whereas early fungicide applications from the beginning of reproductive development increased seed yield by between 36 and 42%. Fungicide mixes of a triazole plus a strobilurin usually gave higher seed yields than using either fungicide type alone.
Keywords: strobilurin, triazole, fungicides, ryegrass, *Lolium* spp., seed yield, stem rust, *Puccinia graminis*.

INTRODUCTION

Seed yields of perennial ryegrass (*Lolium perenne* L.) are affected by several fungal diseases (Latch 1979), but stem rust (*Puccinia graminis* Pers.) is the main limiting disease. In years of epidemics, yield losses can be high, with Kerse & Ballard (1989) reporting four- to five-fold increases in seed yield using cyproconazole to control stem rust. New Zealand trials have reported seed yield responses from fungicides of 27 and 82% in consecutive years (Rolston et al. 2002). Other foliar diseases that can reduce green leaf area during seed fill and that have been identified in Canterbury seed crops are crown rust caused by *Puccinia coronata*, brown blight caused by *Drechslera siccans* and Ramularia leaf spot caused by *Ramularia pussilla* (syn. = *Ovularia pusilla*) (I.C. Harvey, Plantwise, pers. comm.). Traditional stem rust control has used triazole fungicides, especially propiconazole or terbuconazole. More recently available triazole fungicides (e.g. epoxiconazole and prothioconazole) and the strobilurin group (e.g. azoxystrobin), not only control a wider range of diseases but also result in a greater retention of green leaf area than the older triazole fungicides.

This paper summarises seed yield responses in ryegrass crops to fungicides in 19 trials undertaken during a 12 year period, presenting the year-to-year variation in disease incidence and impact, and the response of the crops to application of fungicides.

METHODS

Nineteen fungicide rate, timing and mixture trials were established in farmer fields in the Mid and Central Canterbury region between the years 1995 and 2007 in both irrigated and dryland sites. The crops included both forage and turf perennial ryegrass, as well as forage cultivars of hybrid ryegrass (*Lolium x boucheanum*). The trials evaluated a range of fungicides including triazole and strobilurin fungicides, either as single fungicide treatments or in combinations applied one, two, three or four times in treatment sequences at 2 to 3 week intervals. The fungicides used in the trials were: epoxiconazole (Opus®), propiconazole (Tilt®), prothioconazole (Proline) and terbuconazole (Folicur®) from the triazole group; azoxystrobin (Amistar®SC), pyraclostrobin (Comet®) and trifloxystrobin (Twist) from the strobilurin group; a strobilurin + triazole mix of kresoxim-methyl + epoxiconazole (Allegro®); carbendazim (Bavistan® or Protek) from the benzimidazole group; and mancozeb.

Treatments were applied to the trials between head emergence and seed fill. Crop management for nitrogen fertiliser applications, closing, irrigation and plant growth regulator application was undertaken by the farmers. In two trials, treatments included a preventative approach to disease control (spraying at late head emergence and again at late flowering) versus a reactive approach (fungicides applied when stem rust was first observed in the plots). Plot size was typically 3.2 m × 10 m with treatments replicated four times in randomised block designs. Green leaf area (GLA) along with stem rust and any other leaf diseases were assessed on the seed heads, stems and flag leaves of sampled plants in plots, 1 to 7 days before harvest, by visual assessment of 20 individual tillers randomly selected from each trial plot.

In trials harvested during 1995-1999, seed yield was assessed by hand harvesting at least 1.0 m^2 from each plot. Subsequent trials were machine harvested by cutting a 1.7 m swath from the middle of each plot with a modified plot windrower when seed moisture content (SMC) was 40–42% and then machine threshing with a Wintersteiger 'Elite' plot combine harvester when dry at ca 12% SMC. Field dressed seed was machine dressed to 1^{st} Generation Seed Certification standard (minimum purity 98%) using either an air-screen separator and a Dakota blower or a small Westrup seed cleaner. Data presented are from the highest yielding treatment in each trial. Statistical analyses were carried out with GenStat releases 6 and 7 (VSN International Hemel Hempstead, UK, 2003).

RESULTS

In all 19 trials the highest yielding treatment evaluated in each trial was a significant (P<0.05) increase over the untreated experimental controls (Table 1). Stem rust control was not always a factor in the response (Table 2), although in the 1999/2000 year the yield in the untreated control treatment in turf ryegrass was severely reduced by this disease. In a year with a lower level of stem rust (2000/01), seed yields was positively correlated with the GLA of the crop (Fig. 1), where a 1% increase in GLA was associated with an extra 29 kg seed/ha. Some fungicide treatments were effective at delaying senescence or reducing the impact of diseases such as brown leaf spot and Ramularia leaf spot on GLA, and this was associated with higher seed yields. Often the highest yields in the fungicide trials were from repeated half-label rate applications of epoxiconazole or from triazole/strobilurin mixes, e.g. azoxystrobin + epoxiconazole or kresoxim-methyl + epoxiconazole (Table 1).

In two trials (with different cultivars and in different years) a preventive fungicide approach using predetermined growth stages starting from the beginning of reproductive growth resulted in higher seed yields compared to a reactive management approach, where seed yields were not different to the untreated controls (P>0.05) (Tables 2 & 3). Delaying the start of the fungicide programme, as in the reactive treatments (Table 2), or finishing the programme with triazole only (treatment "Preventative 1") resulted in lower seed yields than when a strobilurin + triazole mix was used (Table 2).

TABLE 1: Mean seed yield (SY, kg/ha) and relative seed yield (RSY, control = 100) responses in forage and turf perennial ryegrass in farm field trials in Canterbury, 1995-2007. Values presented are from the experimental controls and the fungicide treatment giving the greatest increase in seed yield.

Year	Fungicide[1, 2]	Rate (g ai/ha)	Control SY	Fungicide SY	SY gain	RSY
Forage						
1995/96	tebu+carb	187+125	1330	1720	390	129
1996/97	epox+carb	125+125	1300	1510	210	116
1996/97	tebu+carb	187+125	1970	2220	250	113
1996/97	epox+carb or azox+carb	125+125 250+125	1350	1560	210	116
1997/98	prop+ (carb+manc)[2] ×2	190+ 125+960	1310	1620	310	124
1999/00	(azox) ×2	188	1230	2250	1020	182
1999/00	(epox+azox) + (tebu+azox)	31+187 + 107+62	2020	2760	740	136
2000/01	(kres+epox) ×2	125+125	1110	1320	210	119
2000/01	(epox+azox) ×3	125+188	1930	2450	520	127
2001/02	(epox+azox) ×2	31+187	1740	2110	360	119
2002/03	(epox+azox) ×2 + carb	31+125 +125	1400	1540	140	110
2003/04	(pyra+epox) ×2	125+125	1840	2100	250	114
2004/05	(pyra+epox)	200+125	1370	1770	400	130
2006/07	prot ×2	100+100	2160	2850	690	132
2007/08	epox+prot	31+100	1830	2070	240	113
	Average		1590	1990	390	125
Turf						
1999/00	(azox) ×3	125	420	1340	920	319
2000/01	epox ×2 + (epox+azox) ×2	62 + 62+62	1060	1800	740	170
2001/02	(kres+epox) ×2	62+62	2260	2740	480	121
2002/03	(kres+epox) ×2	62+62	1830	2010	180	110
	Average		1390	1970	580	142

[1]azox = azoxystrobin, carb = carbendazim, epox = epoxiconazole, kres = kresoxim-methyl, manc = mancozeb, prop = propiconazole, prot = prothioconazole, pyra = pyraclostrobin, tebu = tebuconazole.
[2]sequential applications repeated either twice (×2) or three times (×3) or sequential mixes in parenthesis.

TABLE 2: Mean seed yield (SY; kg/ha), stem rust disease (% of stems with rust incidence) and green leaf area (%) responses of cv. 'Allsport' turf ryegrass to fungicides applied in reactive (R) or preventive (P) programmes during 2000/01 at Methven, Mid Canterbury.

	Stem elongation		Late flowering				
Treatment	Fungicide[1] & no. of applications	Rate (g ai/ha)	Fungicide & no. of applications	Rate (g ai/ha)	SY (kg/ha)	Stem rust (%)	GLA (%)
Control	nil	0	nil	0	1050	19	50
R1	epox	125	epox ×2	125	1280	8	55
R2	(azox+epox)[2]	187+67	(azox+epox)	187+67	1290	0	60
P1	epox ×2[3]	125	epox ×2	125	1660	0	68
P2	(kres+epox) ×2	125+125	(kres+epox) ×2	125+125	1670	<1	65
P3	epox ×2	125	(kres+epox) ×2	125+125	1670	0	68
P4	epox ×2	67	(azox+epox) ×2	125+34	1720	0	63
P5	epox ×2	125	(azox+epox) ×2	125+34	1730	0	61
P6	epox ×2	67	(azox+epox) ×3	125+34	1800	0	71
P7	epox ×2	125	(azox+epox) ×2	125+67	1820	0	69
LSD (P<0.05)					360	3	12

[1]azox = azoxystrobin, epox = epoxiconazole, kres = kresoxim-methyl.
[2](x+y) = tank mix or proprietary mix.
[3]×2 = repeat application.

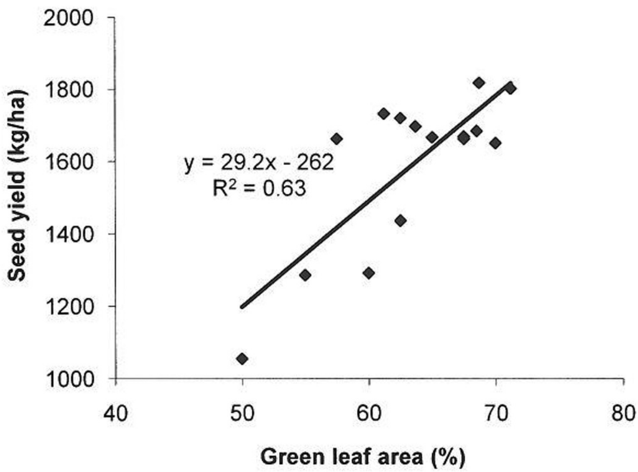

FIGURE 1: Relationship between seed yield and green leaf area in 'Allsport' turf ryegrass during 2000/2001 at Methven.

TABLE 3: Mean seed yield (SY) response of cv. 'Divine' turf ryegrass to fungicides applied as a reactive (R) or in preventive (P) programmes during 2002/03 at Methven, Mid Canterbury.

Treatment	Fungicide[1] & no. applications	Rate (g ai/ha)	SY (kg/ha)
Control	nil	0	1830
R	(kres+epox)[2] ×2[3]	94+94	1840
P1	epox ×3	125	1950
P2-S+ T[4] mix	(trif+epox) ×2	125+67	1990
P3-S + T mix	(kres+epox) ×2	125+125	2000
P4-S + T mix	(pyra+epox) ×2	133+50	2020
LSD (P<0.05)			140

[1]azox = azoxystrobin, epox = epoxiconazole, kres = kresoxim-methyl, pyra = pyraclostrobin, trif = trifloxystrobin.
[2](x+y) = tank mix or proprietary mix.
[3]×2 = repeat application two times.
[4]S+T = strobilurin+triazole mix.

DISCUSSION

This paper summarises field trials undertaken over a 12 year period. In 15 trials with forage ryegrass seed crops the greatest seed yield responses to fungicides averaged 390 kg/ha with a range of increases from 140 to 1020 kg extra seed/ha compared with the untreated experimental controls. This represents a 25% enhancement in seed yield. At current seed prices and fungicide costs the application of fungicide would have been economic in all but one trial.

In the four turf ryegrass trials the seed yield increase from fungicides averaged 580 kg/ha with a range of increases from 180 to 920 kg/ha. The larger response in turf ryegrass is consistent with seed grower experiences with turf cultivars originating from the United States (M. Kelly, PGGWrightson Seeds, pers. comm.). Ryegrass seed yield responses to fungicides in turf ryegrass in Oregon (USA), the largest seed growing region of the world, have ranged from 0 to 100% between sites and cultivars (Mellbye et al. 2007, 2008).

The failure of the reactive fungicide treatment, i.e. waiting for the disease to appear before beginning treatments, is also consistent with seed grower experiences. Stem rust often develops under the leaf sheaths of the flag leaves of infected plants, and only becomes apparent later when spore pustules rupture onto the stem surfaces (Bill Pfender, USDA-ARS Forage Seed Laboratory, Corvallis, Oregon, pers. comm.).

In some years the level of stem rust infection was low, but seed yield increases occurred and in these years there was a positive effect of fungicides enhancing GLA associated with improved seed yield.

During the period covered in this paper, the active ingredients of the fungicides available and commonly used by seed growers has changed, with new triazole fungicides and the strobilurin fungicides becoming available. In all but two trials a fungicide mixture gave the highest seed yield. The effective mixes were often a strobilurin plus triazole combined at a half label rate for each.

The severity of stem rust infection varied between years, with large seed yield responses to fungicides in 1999/2000, and minimal responses in 2002/03 (Table 1). In Oregon a stem rust prediction model has been developed based on an accumulated growing degree days and the presence of dew on leaves at sunrise (Pfender et al. 2004; Mellbye et al. 2008). This model requires evaluation in New Zealand since unexplained variations occur in incidence of the disease both between regions of Canterbury within a growing season and between different growing seasons.

While the data presented here indicates an association between increased GLA and seed yield (Fig. 1), recent research by Trethewey & Rolston (2009) suggests that flag leaves of ryegrass are not important as sources of carbohydrate for seed heads, but that the seed heads are more important. Thus fungicides may not only keep leaves green, but the impact on seed yield may be the result of maintaining active seed head photosynthetic tissues.

Some fungicides used for stem rust control can affect endophyte (*Neotyphodium lolli*) transmission (Rolston et al. 2002). Recommendations on fungicide(s) for seed crops should balance the benefits of protecting seed yield and the requirement for high levels of animal-safe endophyte in seed.

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