

Grass seed yields increased with plant growth regulators and fungicides

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Abstract

Seed yields of ryegrass and tall fescue have increased rapidly over the last seven years; the best farm yields are now reaching 3000 kg/ha, up from 2000 kg/ha. These increases are largely due to the adoption of technologies developed from research funded from grower crop levies and effective technology transfer programmes. The key technologies are (1) the adoption of trinexapac ethyl (TE), a plant growth regulator that blocks gibberellic acid biosynthesis and reduces lodging; and (2) new generation triazole and strobilurin fungicides that give improved disease control and extend the period that green leaf area is maintained on crops. Seed yield data from 10 ryegrass and 6 tall fescue trials with TE, and from 13 fungicide trials are presented. The average seed yield increase in tall fescue treated with 200 g TE/ha and ryegrass with 400 g TE/ha was 67% and 50% respectively. In fungicide trials, seed yields in forage perennial ryegrass were increased by 20% and in turf ryegrass by 42%. A survey of growers indicated 95% of ryegrass growers and 100% of tall fescue growers had adopted the use of TE three years after the commercial release of the product.

Keywords: fungicides, plant growth regulators, ryegrass, seed yield, strobilurin, tall fescue, triazole, trinexapac

Introduction

The highest seed yields of perennial ryegrass (*Lolium perenne*) and tall fescue (*Festuca arundinacea* syn. *Schedonorus phoenix*) being achieved by herbage seed growers have increased significantly over the last seven years. In the 1994/95 annual "Ryegrass 2000" awards there were only three crops of ryegrass that exceeded 2000 kg/ha (Rolston 1995). In the 2002/03 season at least three farmers achieved yields of more than 3000 kg/ha with perennial ryegrass crops in Canterbury/North Otago. Tall fescue yield increases have been less dramatic, but have also steadily increased in recent years. The adoption of technologies has contributed to these seed yield gains; especially the impact of the new plant growth regulator (PGR) Moddus® trinexapac-ethyl (TE) and new fungicides, especially the introduction of more persistent triazole fungicides and a new class of fungicides, the strobilurin group. Other factors contributing to higher seed yields include a better

understanding of the use of nitrogen (N) (Rowarth *et al.* 1998), and the expansion of the area grown under irrigation.

PGR technology for grass seed production is not new. In the 1980's, paclobutrazol (Cultar) was widely tested and trials demonstrated that seed yield responses were achieved through the control of lodging in ryegrass (Hampton 1986). The product was not commercialised for arable crops in New Zealand because of soil residue problems for other crops in the rotation, but is sold in NZ for use on apples to block gibberellic acid (GA) synthesis and shorten internode length of new growth. The PGR chlormequat (CCC or Cycocel) was shown to increase seed yields by between 34 and 43% in plot trials (Hampton 1986), and was used by ryegrass seed growers during the 1990's although on farm seed yield responses were typically 10 to 15% (unpublished data). Chlormequat did not control lodging and the lack of a visual response after application reduced adoption rates by growers. TE was commercially released in NZ in 2000 as a PGR that enhances seed yields in ryegrass. The mode of action of TE is as an acylcyclohexanedione inhibitor of gibberellic acid (GA) biosynthesis (Rademacher 2000). It retards grass growth by inhibiting hydroxylation of the growth inactive form of GA to the active form (King *et al.* 1997). This results in stem shortening of reproductive tillers and their increased efficiency in terms of increased number of seeds per spikelet and improved floret site utilization (Chastain *et al.* 2003).

The main disease in ryegrass seed production is stem rust (*Puccinia graminis*) and in years of epidemics losses can be high (Kerse & Ballard 1989). Traditional control methods used a preventative triazole fungicide e.g. propiconazole (Tilt) or terbuconazole (Folicur). The development of a new class of fungicides, the strobilurin group (e.g. Stroyb®, Amistar®, Allegro®) which not only control a wide range of diseases but provides a greater enhancement of green leaf area than the older triazole fungicides, has offered new opportunities for grass seed producers.

This paper reports seed yield responses of ryegrass and tall fescue in trials with PGR and fungicides that contributed to a high adoption rate of these products by NZ herbage seed producers.

Table 1 Seed yield (SY) response at nine ryegrass trial sites in growers' fields for untreated control and trinexapac ethyl (TE) 400 g/ha.

Trial location & year	Dryland/ irrigated	Cultivar	Control SY (kg/ha)	TE SY (kg/ha)	SY gain (kg/ha)	relative SY (control =100)	LSD (5%)
Irwell 2000/2001	irrigated	Quartet LF PRG	1730	2480	750	143	111
Irwell 2001/02	irrigated	Quartet LF PRG	1590	1280	-310	81	163
Wakanui 2000/2001	irrigated	Impact HRG	2290	2950	660	129	202
Irwell 2001/2002	irrigated	Feast IRG	1180	1830	650	155	314
Methven 2001/2002	dryland	Majesty turf PRG	2250	2900	650	129	243
Lyndhurst 2001/2002	dryland	Nui PRG	1460	2030	570	139	180
Methven 2000/2001	dryland	Nui PRG	900	1750	850	194	188
Methven 2001/2002	dryland	Nui PRG	1050	1580	530	150	270
Dunsandel 2001/2002	irrigated	Aries PRG	700	1600	900	229	184
Average			1460	2040	580	150	

HRG = hybrid ryegrass; IRG= Italian ryegrass; LF = late flowering perennial; PRG= perennial ryegrass.

Table 2 Effect of the plant growth regulator trinexapac-ethyl (TE) on stem length, seed yield (SY), number of seeds, thousand seed weight (TSW) and floret site utilization (FSU) cv. "Nui" at AgResearch farm, Lincoln.

TE rate (g/ha)	Length (cm)	SY (kg/ha)	No. seeds (⁰⁰⁰ /m ²)	TSW (g)	FSU (%)
0	105.5	1690	65.7	2.56	15.2
400	92.5	2090	85.2	2.45	19.9
LSD (5%)	7.9	260	9.7	0.09	1.6

Material and methods

PGR ryegrass

Nine trials were conducted during 2000/2001 and 2001/2002 using farmer fields in the mid Canterbury region. The trials included cultivars of perennial (*Lolium perenne*), hybrid (*L. x boucheanum*) and Italian (*L. multiflorum*) ryegrass (Table 1) in both irrigated and dryland sites. Crop management was undertaken by the farmer. Trinexapac ethyl (TE) in the form of Moddus® (250 g TE/L) was applied at 0 and 400 g TE/ha in all trials (and in two at six rates from 0–800 g TE/ha) at Zadocks growth stage (GS) 32 (when 2 nodes were present on most reproductive tillers). Plot size was 3.2 m x 10 m long and replicated four times in a randomised block design. At harvest a 1.7 m swath was cut from the middle of each plot with a modified plot windrower at between 40 and 42% seed moisture content and subsequently machine combined with a Wintersteiger 'Elite' plot combine harvester when dry. Field dressed seed was machine dressed to 1st Generation Seed Certification standard (minimum purity 98%) using air-screen separators. A separate trial with Nui perennial ryegrass at Lincoln (2000/2001) was analysed for components of yield and hand harvested (Table 2). Lodging was assessed by visual estimation and scored as a percentage of plot lodged. Stem length was measured

on 30 reproductive tillers per treatment cut at ground level post anthesis. Floret site utilization (FSU) was calculated as the number of saleable (dressed) seeds produced from the number of florets counted post anthesis (Elgersma 1985).

PGR tall fescue

Six trials were conducted between 2000 and 2003 using sites in farmers' fields (at Wakanui and Greenpark) and a research station site (Lincoln). The sites were on a good quality soil (Wakanui silt loam) and irrigated. General management included autumn nitrogen (N) 100 to 150 kg N/ha; and spring applications of 100 to 150 kg N/ha applied at 50 kg N/application. Moddus® (250 g TE/L) was applied at Zadocks GS 32 at rates of 0, 200 and 300 g TE/ha. Treatments were replicated four times in a randomised block design. All plots were hand harvested by sampling either a 1.0 or 1.2 m² quadrat, air dried in hessian sacks and machine threshed and cleaned to a 1st Generation Seed Certification standard.

Fungicides

Thirteen trials were established in farmer fields between the years 1995 and 2003 in crops of both forage and turf perennial ryegrass. The trials evaluated a range of fungicides including triazole fungicides 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. Treatments were applied between head emergence and seed fill. Crop management was undertaken by the farmers. Plot size was 3.2 m x 10 m long and replicated four times in a randomised block design. Harvesting was similar to the method described above for PGR trials in ryegrass. The data presented are from the highest yielding treatment in each trial. Green leaf area was assessed on the flag leaf preharvest based on visual assessment of 20 individual tillers per plot collected by random sampling.

Cost-benefit analysis

The cost structures used in the analysis were: application of agrichemicals at \$20/ha per application; TE at 300 and 400 g/ha = \$170 and \$230/ha respectively; fungicide using a triazole/strobilurin mix, \$100/ha per application with 2 applications on forage and 3 applications on turf. Seed prices used were \$1.80/kg for ryegrass and \$3.00/kg for forage tall fescue. Net benefit was calculated as the value of the extra seed, minus treatment costs.

Survey

Crop inputs on 24 grass seed crops in the South Canterbury Sustainable Grass Seed Group were surveyed as part of a baseline data collection in May 2003. Data on PGR use on tall fescue were collected during on-farm crop inspections on 40 farms growing cv. Advance tall fescue in 2003.

Results

Ryegrass PGR

There was a consistent, significant ($P < 0.05$) and large seed yield response in nine out of 10 trials (Table 1) with the 400 g TE/ha treatment resulting in an average 50% increase in seed yields from 1400 to 1980 kg/ha. In only one trial with the late flowering ryegrass cv Quartet was there a negative response, although in the previous year a positive response was recorded with Quartet (Table 1). In the other nine trials the positive response occurred in a wide range of early to mid-maturing cultivars, forage and turf types, perennial, hybrid and annual ryegrass, both in dryland and under irrigation. The seed yield response was associated with stem shortening (Table 2) and a reduction in lodging (Figure 1), especially at anthesis, resulting in more saleable seeds per unit area and an increased FSU% (Table 2).

In the rate response trials there was a significant linear increase in seed yield over a wide range of TE rates up to the highest rate tested (800 g TE/ha equal to 3.2 l/ha Moddus) associated with a decline in lodging, both in perennial ryegrass (Figure 1) and in Italian ryegrass (Figure 2). In Feast Italian ryegrass there was 1.9 kg

Figure 1 Seed yield and lodging response in dryland Nui perennial ryegrass to rates of trinexapac-ethyl (Lyndhurst 2001/2002) (vertical bars indicate LSD $P < 0.05$).

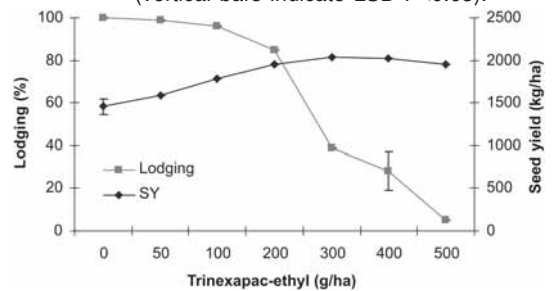


Figure 2 Seed yield (SY) and lodging (L) response in Feast Italian ryegrass to rates of trinexapac-ethyl (Irwell, 2001/2002) (vertical bars indicate LSD $P < 0.05$).

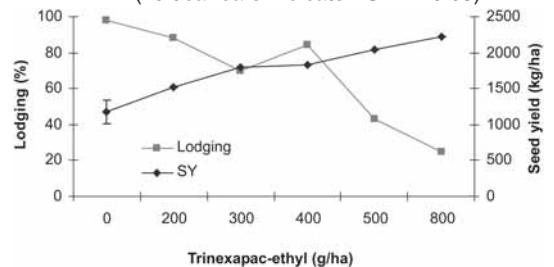


Figure 3 Relationship between relative seed yield (untreated control = 100) and lodging (combined data for perennial ryegrass and Italian ryegrass).

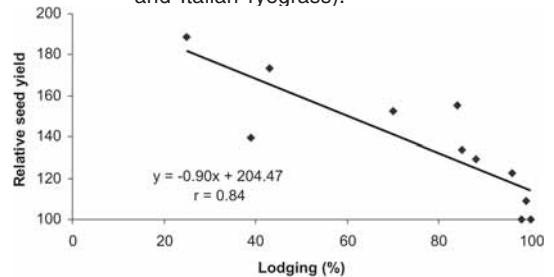


Figure 4 Relationship between seed yield and green leaf area in cv Allsport turf ryegrass (Methven 2000/2001).

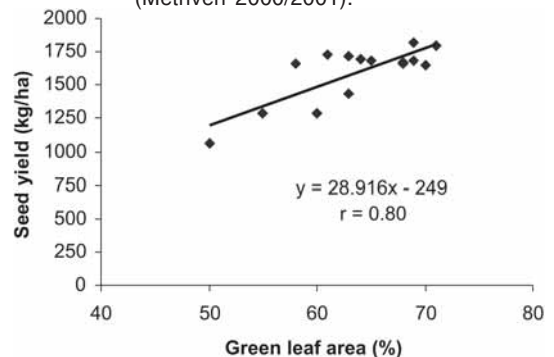


Table 3 Seed yield (kg/ha) from seven trials over four years of tall fescue treated with three rates of trinexapac-ethyl (TE).

Year	Cultivar	TE (g ai/ha)			LSD (5%)
		0	200	300	
2000/2001	Advance	600	1040	930	307
2000/2001	Advance	439	618	665	197
2001/2002	Advance	560	1090	1080	240
2001/2002	Vulcan	570	750	775	NS
2002/2003	Advance	490	890	1030	113
2002/2003	Advance	683	1058	1057	106
Average (kg/ha)		544	904	918	119
Relative SY		100	167	172	

Table 4 Seed yield (SY) responses for forage and turf perennial ryegrass with fungicide treatments for blind seed and stem rust control. The best fungicide treatment result from each trial is presented, with sequential repeat applications either twice (x2) or three applications (x3) or sequential mixes in parenthesis.

Year	Fungicide + rate (g ai/ha)	Control SY (kg/ha)	Fungicide SY (kg/ha)	SY gain (kg/ha)	Relative SY (control = 100)
Forage					
1995/1996	tebuconazole 187 g + carbendazim 125 g	1330	1720	390	129
1996/1997	epoxinconazole 125 g + carbendazim 125 g	1300	1510	210	116
1996/1997	tebuconazole 187 g + carbendazim 125 g	1970	2220	250	113
1996/1997	epoxinconazole 125 g + carbendazim 125 g or azoxystrobin 250 g + carbendazim 125 g	1350	1560	210	116
1997/1998	propiconazole 190 g + (carbendazim 125 g + mancozeb 960 g) 2x	1310	1620	310	124
1999/2000	(epoxinconazole 31 g + azoxystrobin 187 g) + (tebuconazole 107g + azoxystrobin 62 g)	2020	2760	740	136
2000/2001	(kresoxim-methyl 125g + epoxiconazole 125 g) x2	1110	1320	210	119
2001/2002	(epoxinconazole 31 g + azoxystrobin 187 g) x2	1740	2110	360	119
2002/2003	(epoxinconazole 31 g + azoxystrobin 125 g) x2 + carbendazim 125 g	1500	1810	310	120
	Average				
	LSD (5%) averages	137			
Turf					
1999/2000	(azoxystrobin 125 g) x3	420	1340	920	319
2000/2001	epoxinconazole 62 g x2 + (epoxinconazole 62 g + azoxystrobin 62 g) x2	1060	1800	740	170
2001/2002	(kresoxim-methyl 62g + epoxiconazole 62 g) x2	2260	2740	480	121
2002/2003	(kresoxim-methyl 62g + epoxiconazole 62 g) x2	1830	2010	180	110
	Average	1392	1973	580	142
	LSD (5%) averages	511			

Table 5 Economic benefit based on nine ryegrass (RG) and six tall fescue (TF) trials with plant growth regulator trinexapac ethyl (TE), and nine forage and four turf ryegrass trials with fungicide.

Treatment	Yield response (kg/ha)	Revenue (\$/ha)	Cost (\$/ha)	Benefit (\$/ha)
TE 400 g RG	580	1044	250	794
TE 300 g TF	360	1080	190	890
Fungicide forage RG	310	558	200	358
Fungicide turf RG	580	1046	300	746

extra seed produced for every 1 g/ha increase in TE rate (Figure 2). There was a strong, negative relationship between increased lodging and a decline in relative seed yield (Figure 3).

Tall fescue

Seed yields were significantly increased ($P < 0.05$) in five out of six trials when Moddus was applied at 200 and 300 g TE/ha (Table 3). The average seed yield increase was 67 and 72% respectively for the two rates evaluated. As with ryegrass the TE treatments reduced stem length and lodging. Farmers reported that harvesting was considerably easier when they used TE than with no TE, with shorter straw being easier to handle during windrowing and combine harvesting (Rolston *et al.* 2003).

Fungicides in ryegrass

In forage and turf perennial ryegrass seed yields were significantly increased ($P < 0.05$) in all 13 trials by the best treatments evaluated in each trial (Table 4). Stem rust was not always a factor in the response, although in the 1999/2000 year the untreated control treatment in turf was severely reduced in yield by this disease. In some years with low levels of stem rust, seed yields were positively correlated with the green leaf area (GLA) of the crop (Figure 4), with a 1% increase in GLA associated with an extra 29 kg seed/ha. Some fungicide treatments were very effective at delaying senescence or reducing the impact of fungi such as leaf spot diseases caused by *Drechslera siccans* and *Ovularia* spot (*Ovularia pusilla* syn *Ramularia pusilla*) on GLA. Often the highest yields in the fungicide trials were from repeated half-label rate applications of epiconazole (Opus) or from triazole/strobilurin mixes e.g. epoxinconazole + azoxystrobin (Amistar) or epoxinconazole + kresoxim-methyl (Allegro).

Economic benefit

In nine trials, Moddus applied at 400 g TE/ha to ryegrass increased seed yield on average by 580 kg/ha with an average net benefit \$794/ha (Table 5). In tall fescue the benefit from TE was \$890/ha while in fungicide trials the net benefit was \$358 and \$745/ha respectively for forage and turf cultivars.

Discussion

Yield increases in the TE trials are attributed to the effect of the PGR on reduced lodging at anthesis, improved carbon allocation to the ear at the expense of vegetative tillers (Hampton & Hebblewaite 1984) resulting in an increased FSU (Table 2). The cause of the negative result in the late flowering ryegrass was not determined but the result fits a pattern reported in the United Kingdom,

where nil responses in late flowering perennial ryegrass have occurred (A. Burgon, British Seed Houses pers. comm.). Plant growth regulators and fungicides are expensive inputs, but the magnitude of responses, coupled with the reliability of the response across seasons and the economic benefits have resulted in a rapid adoption of the two technologies described in this paper. Two surveys on TE use show high adoption rates; with 95% of ryegrass growers in South Canterbury and 100% of tall fescue growers now using this technology (Rolston *et al.* 2003). The Foundation for Arable Research (FAR) has had an effective technology transfer programme to ensure seed growers are informed of new trial results, including mailing of all growers with a summarized research report of each trial using the FAR Herbage Update service, emailing growers with highlights, running on-farm field days at least twice a year and winter seminars.

In the last two years (2001/2002 and 2002/2003) there were no stem rust epidemics, and in those two years little or no stem rust was seen in many forage ryegrass seed crops. New research is now aimed at being better able to predict epidemics to allow growers to reduce the amount of fungicide without risking crop failure. Previous studies by the authors have shown that in years of high stem rust pressure reactive programmes resulted in poor disease control and lower seed yields in contrast to programmed treatment regimes.

The development of novel endophytes and in particular the release of AR1 endophyte required testing of fungicide programmes used in ryegrass to validate their safety on endophyte. In a field study none of the fungicides tested for stem rust control had an effect on AR1 viability at harvest (Rolston *et al.* 2002). In the future as new fungicides are released for use on ryegrass it will be necessary to test their safety on endophyte viability at harvest and after storage.

Conclusion

Trinexapac ethyl Moddus® first released in 2000 is a new PGR that has resulted in seed yield increases averaging 50% in ryegrass and 67% in tall fescue trials. New fungicides have increased seed yields by either controlling disease and/or enhancing green leaf area. Both technologies have increased economic returns and have been readily adopted by seed producers.

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