Italian ryegrass seed yield: trinexapac-ethyl and closing date interaction

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Abstract

Two field trials with Italian ryegrass (*Lolium multiflorum*) evaluated two spring defoliation dates and four trinexapac-ethyl (TE) rates (0 to 600) in 200 g/ha increments. Delaying the final spring defoliation from early to mid-October (industry practice) by 10 to 13 days increased seed yields significantly and by an average of 1,270 and 830 kg/ha at the two sites. Seed yields with delayed closing and TE application averaged 3,570 kg/ha. The optimum TE rate was between 200 and 400 g/ha. Seed yield response to TE and later spring defoliation was positively correlated (R^2=0.62) with delayed lodging. Delayed closing increased reproductive tiller density. The conversion of seeds set three weeks after flowering to saleable seed was 31% in the control and 48% for the highest seed yield treatment (late closing and 400 g TE/ha). Harvest index increased from <10% in the early closed nil TE treatment to >20% in late closed with TE treatments. Delayed lodging and better light interception by the standing crop is thought to drive these responses.

Additional keywords: components of yield, harvest index, *Lolium multiflorum*, lodging

Introduction

Trinexapac-ethyl (TE) is a plant growth regulator that reduces internode length in many grass and cereal (Poaceae) species resulting in delayed lodging and increased seed yields (Rolston *et al*., 2010a). TE usage and seed yield response under New Zealand conditions is well documented in perennial ryegrass (*Lolium perenne* L.) seed crops (Rolston *et al*., 2004; Chynoweth *et al*., 2010). There have been fewer reports of TE response in annual/Italian ryegrass (*L. multiflorum* Lam.) seed crops. In New Zealand it is standard practice to defoliate ryegrass seed crops throughout late winter and early spring until the start of stem elongation. The final defoliation is commonly in early to mid-October at the appearance of the first node on reproductive stems at Growth Stage (GS) 30/31) Zadoks *et al*., 1974), although recent research has demonstrated that late October defoliation results in higher seed yields (Rolston *et al*., 2010b). The purpose of this research was to investigate the seed yield response of Italian ryegrass to four rates of TE when final defoliation was at either mid or late October.

Materials and Methods

The two trials were in seed growers fields and all inputs (herbicides, fertiliser, fungicides and irrigation (Table 1) were managed by the growers except TE application and the date of final defoliation. Experiment 1 was situated at Wakanui (mid-Canterbury, 43° 56’ S, 171° 52’ E) on a stony soil sown with a tetraploid westernwolds annual ryegrass cultivar (cv.) ‘Archie’. Experiment 2 was situated at Milford (South Canterbury, 44° 14’ S, 171° 21’ E) on a silt loam soil sown with a diploid Italian ryegrass cv. ‘Crusader’.

The trial design was two closing dates with four TE (a.i. 250 g/l trinexapac-ethyl applied as ‘Moddus’) rates: 0, 200, 400 and 600 g/ha, and with 400 g TE + 3000 g/ha chlormequat chloride (CCC) (applied as ‘Cycocel’ a.i. 750 g CCC/l) in a randomized block design with four replicates. Plots were 3.2 × 10 m. The grower’s last defoliation date at GS 30/31 (Zadoks *et al*., 1974) was imposed through grazing with sheep and is referred to as the early closing date. The late closing defoliation (GS 30.5/31) was imposed by cutting to 7 cm with a self-propelled rotary mower 10 to 13 days later. All TE treatments were applied at GS 32, approximately 28 days after final defoliation. Herbage dry matter mass at TE application time was assessed from 0.25 m^2 quadrat cuts. Weekly assessments of lodging were made from first anthesis and the days to 50% lodging (crop at 45° angle) was calculated.

Three to five days before the crop was swathed a 0.25 m^2 quadrat cut to ground level was taken from each plot to determine crop mass, stem length (cm), seed head density and spikelets per head. In a subset of plots, fertile florets per spikelet were counted and percentage seed set determined. Thousand seed weight (TSW) at harvest was used to calculate seeds per unit area and seeds per spikelet. Harvest index was calculated as seed mass/(seed mass + harvest mass). At harvest a 1.7 × 10 m swath was windrowed at approximately 42% seed moisture content (SMC). Plots were threshed 6 to 12 days later at approximately 12% SMC with a Sampo plot combine. The seed was dressed to a 1st Generation seed certification standard (≥98% purity) and the machine dressed seed yield/ha (12% SMC) calculated. Saleable seeds are calculated as the number of seeds in the machine dressed seed sample.

Data analysis

Data analysis by two way ANOVA was undertaken using GenStat (version 9, VSN International Ltd, UK) to determine least significant differences (LSD) (P=0.05). Correlation coefficients were calculated using MicroSoft Excel.

Table 1: Key inputs and activities in trial 1 (Wakanui site) and trial 2 (Milford site).

Activity	Wakanui	Milford
Cultivar and ploidy	Archie (4N)	Crusader (2N)
Sow date	23 March 2009	22 March 2009
Spring nitrogen applied (kg/ha)	184	183
First closing date	10 October 2009	17 October 2009
Second closing date	20 October 2009	30 October 2009
TE application (first and second closing)	6 and 19 November 2009	10 and 28 November 2009
Dry matter at first TE application	5050 kg DM/ha	2550 kg DM/ha
Dry matter at second TE application	3330 kg DM/ha	3100 kg DM/ha
Irrigation applied	270 mm	175 mm
Windrow dates (first and second closing)	18 and 21 January 2010	2 and 4 February 2010
Harvest date	30 January 2010	8 February 2010

Results

Both trials were high yielding with average seed yields for all TE late closed treatments of 3,550 and 3,580 kg/ha at Wakanui and Milford respectively and averaging 3,370 if nil TE included (Table 2).

Closing date and trinexapac-ethyl interaction.

There was a significant defoliation date by TE rate interaction for both trials (Table 2). At Wakanui for the early closing date seed yield was increased by 200 g TE/ha, but there was no further increase at higher rates, compared with a slightly increasing seed yield with increasing TE rate for the later closing date. At Milford seed yield did not differ between closing dates when no TE was applied but when TE was applied, the later closing date showed a greater response compared with the early closing (Table 2).

Closing date

At Wakanui, delaying closing by 10 days increased average seed yield from 2,100 to 3,370 kg/ha (Table 2). At Milford delaying closing by 13 days increased average seed yields from 2,540 to 3,370 kg/ha (Table 2). The mean TE seed yield increase above nil TE was 730 and 900 kg/ha for the early and late closing at Wakanui and 590 and 1,430 kg/ha for early and late closing at Milford.

Trinexapac-ethyl response

There was a significant ($P<0.001$) seed yield response to TE at both sites; with no increase above 200 g/ha at Wakanui and above 400g/ha at Milford (Table 2). TE treatments (across rates) increased seed yields by 29 to 64% respectively at Milford and Wakanui. There was no seed yield advantage in adding CCC to TE (Table 2).

Table 2: Effect of trinexapac-ethyl (TE) and chlormequat chloride (CCC) and closing date on seed yield (kg/ha) at Wakanui and Milford.

TE	Closing date (Wakanui)			Closing date (Milford)		
(g/ha)	10-Oct	20-Oct	Mean[1]	18-Oct	30-Oct	Mean
0	1510	2650	2080b	2070	2230	2150c
200	2510	3380	2950a	2280	3440	2860b
400	2330	3580	2960a	2660	3680	3170a
600	2200	3630	2920a	2950	3630	3320a
400 + 3000 CCC	1930	3620	2780a	2760	3880	3290a
Mean	2100	3370		2540	3370	
	$LSD_{(0.05)}$	F-value prob.		$LSD_{(0.05)}$	F- value prob.	
TE	243	<0.001		124	<0.001	
Close	153	<0.001		197	<0.001	
TE × Close	343	0.005		278	<0.001	

[1]Means within a column followed by the same letter are not significantly (P>0.05).

Stem shortening

Increasing TE rate and later closing both significantly (P<0.001) decreased stem length at both trial sites (Figure 1). Delaying the date of closing increased the responsiveness of the Italian ryegrass to TE, with the later closing having almost twice the amount of stem shortening compared to the earlier closing, 8 and 4 cm per 100 g TE respectively (Figure 1a and 1b) at both sites.

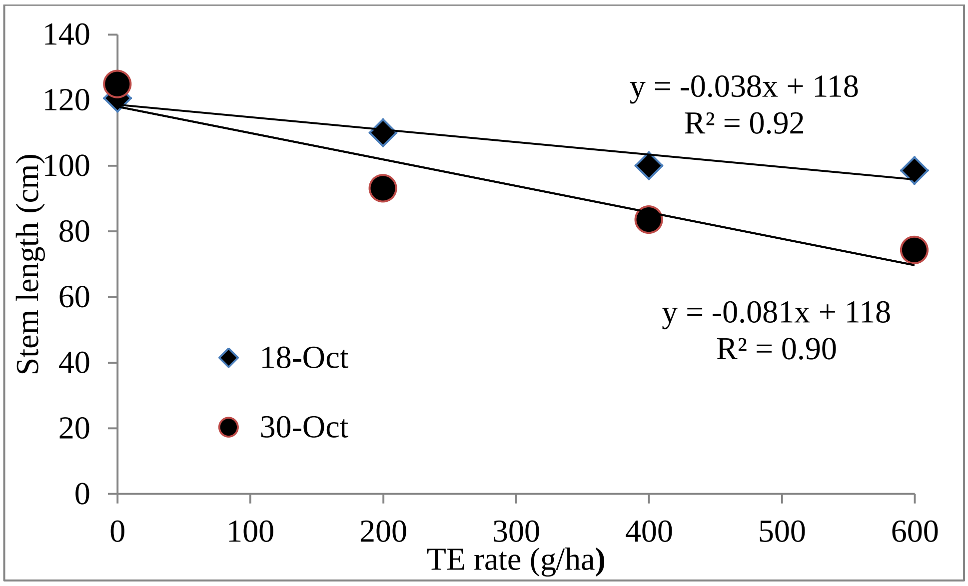

Figure 1a: Change in reproductive stem length with increasing trinexapac-ethyl (TE) rates for two closing dates in cv. 'Crusader' at Milford. ($LSD_{(0.05)} = 13$).

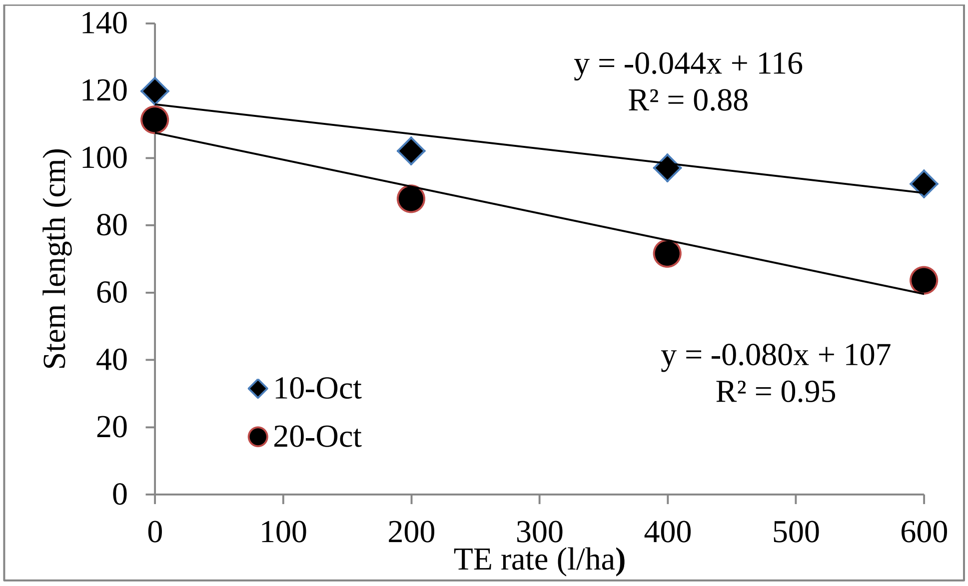

Figure 1b: Change in reproductive stem length with increasing trinexapac-ethyl (TE) rates for two closing dates in cv. 'Archie' at Milford. ($LSD_{(0.05)}$ = 9).

Days to 50% lodging

At both sites there was less lodging for the later closing compared with early closing for all TE rates. The number of days from anthesis to 50% lodging was delayed significantly ($P<0.001$) by increasing TE rate and later closing date; e.g. from 5 days (nil TE early close) to 40 days (600 g TE later closed) (Figure 2). There was a positive correlation (R^2=0.62) between seed yield and days to 50% lodging; with each days delay increasing seed yield by 45 kg/ha.

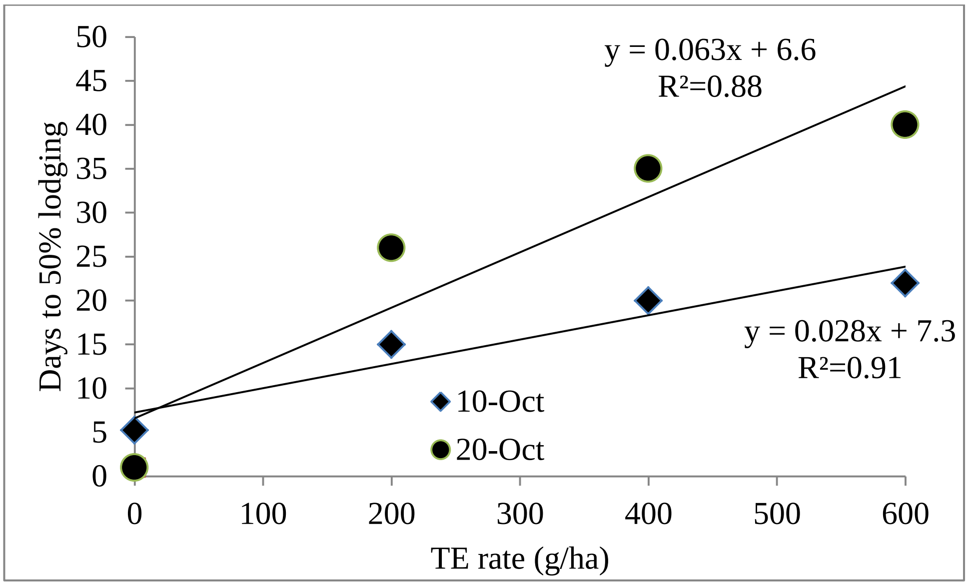

Figure 2: Change in days to 50% lodging with increased trinexapac-ethyl (TE) rates for the two closing dates on cv. 'Archie' at Wakanui.

Components of yield

Data from only the 400 g TE/ha treatment is presented to illustrate the size of the key components as many of the components were unchanged by the treatments. While the seed yield for 400 g TE/ha at the later closing date was similar between the two sites, the components of yield differed, partly reflecting the difference in ploidy (4N at Wakanui and 2N at Milford) (Table 3). The 4N crop (compared to the 2N crop) had a lower head density, fewer seeds/m^2, fewer seeds/head but a higher TSW resulting in a higher seed yield/head compared with the 2N crop (Table 3).

Seed head density

At Wakanui there was a low head density, (average 1000 heads/m^2) and no effect of closing date. There was a significant (P=0.01) TE rate effect on head density, with more heads at 400 g TE (1110 heads/m^2) than for nil TE (820 heads/m^2). At Milford delayed closing increased head density from 1,620 to 2,020 (P=0.003) but there was no TE effect on head density.

Table 3: Comparison of main components of seed yield between the two sites for trinexapac-ethyl at 400 g/ha applied to plots at the later closing date at Wakanui (20 October) and Milford (30 October) in the 2009-10 season.

Component	Wakanui[1]	Milford[2]
Harvest DM mass (t/ha)	14.5	15.6
Seed heads (m^2)	1190	1730
Spikelets/head	23.7	23.5
Seeds set/spikelet	6.5	7.2
Seed set %	86	85
TSW (g)	4.68	2.72
Seed yield (kg/ha)	3580	3680
Seeds ('000/m^2)	77	135
SS-SS[3] (%)	43	49
Harvest Index (%)	19.8	19.1
Seeds/head	65	81
seeds/spikelet	2.8	3.5
seed yield/head (mg)	304	221

[1]cv. 'Archie' tetraloid; [2]cv. 'Crusader' diploid; [3]SS-SS = saleable seeds/seeds set.

Spikelets

At both sites delayed closing reduced spikelets/head significantly, by 1.3 and 2.2 spikelets/head for Wakanui and Milford, respectively, compared with an average of 24 spikelets per head in the early closing at both sites. There was no TE rate effect on spikelet number/head.

Seed set

The percentage of florets that produced a developing seed averaged 81% and 86% at Wakanui and Milford respectively. There was no treatment effect on seed set %; but numbers of seed set/m^2 were increased at Wakanui (but not at Milford). At Wakanui increasing TE rate significantly (P=0.02) increased the number of seeds set from 128,000 (nil Moddus) to an average of 16,800 per m^2 for all TE treatments. Closing date had no effect on the number of seeds set at either site. At Milford seeds set averaged 296,000 per m^2.

Saleable seeds

Treatments significantly increased saleable seed numbers. Not surprisingly seed yield and number of saleable seeds per m^2 were highly correlated (R^2=0.98 at Milford). Trinexapac-ethyl and later closing increased the percentage of seeds set that became saleable seeds (SS-SS). At Wakanui SS-SS% increased from 31 to 48% for the early and later closing respectively. Increasing TE rate from 0 to 600 g TE/ha significantly increased the number of saleable seeds per spikelet from 2.1 to 2.9 (Wakanui) and from 1.6 to 2.6 (Milford). Across all treatments one seed per spikelet added 1060 and 1140 kg/ha extra seed at Wakanui and Milford respectively.

Thousand seed weight (TSW)

At Wakanui TSW was 5.0 g in the control reducing to 4.5 g with increasing TE rate and to 4.0 g when CCC was added to TE ($LSD_{(0.05)}$ = 0.6). At Milford the TSW declined from 2.9 to 2.7 g ($LSD_{(0.05)}$ = 0.1) with increasing TE rates from 0 to 600 g TE/ha.

Crop mass

Crop mass at harvest was 14.5 and 15.6 t DM/ha at Wakanui and Milford respectively. There was a significant (P<0.001) closing date effect at Wakanui where there was less harvest mass with later closing, 12.9 versus 15.9 t/ha for early closing.

Harvest index

Harvest index increased from 9.5% (nil TE, early closing) to 23.2% (600 g TE/ha, late closing) ($LSD_{(0.05)}$ = 3.1) at Wakanui. Harvest index averaged 11.8% for the early closing and 20.8% for late closing ($LSD_{(0.05)}$ = 1.4) at Milford.

Discussion

The seed yields in these two trials are the highest recorded in Italian ryegrass trials in New Zealand. Several treatments had seed yields greater than 3,500 kg/ha which by international standards are high seed yields (W.C. Young III pers. comm., 2012).

There were dramatic seed yield responses to delayed closing and TE application (Table 2). Both growers had closed at a date they perceived as being late because stem elongation had started and reproductive tiller growing points could be removed by grazing. At Wakanui delayed lodging, associated with TE and delayed closing, resulted in an extra 45 kg seed/ha for every day's delay in reaching 50% lodging. This compares with the results from eight perennial ryegrass trials where an average increase of 24 kg seed/ha for every day's delay in 50% lodging was reported (Rolston *et al*., 2010a).

The closing date effects are consistent with five previous FAR funded trials that all support the conclusion that late October closing is optimum for irrigated Italian ryegrass. In this study and previous trials (Rolston *et al*., 2010b), delayed closing was associated with removal of reproductive growing points yet the seed head density was increased. This requires further investigation. The TE response is also consistent with previous FAR trials where optimum TE rates between 200 and 400 g/ha have been reported (Rolston and McCloy, 2007).

Delayed lodging was highly correlated with enhanced seed yield, probably associated with improved canopy light interception (Rolston *et al*., 2007). Later closing enhanced the TE response. At Wakanui this could be explained by the lower crop mass in the second closing at TE application effectively increasing the concentration of TE in plant tissue after application. However, this was not the case at Milford. Possibly the rate of stem elongation is more rapid in later closed crops and TE effectiveness is enhanced under more rapid stem elongation. Further research is needed into this.

The increase in Italian ryegrass seed yield was associated with shorter stems and delayed lodging, resulting in an improved reproductive efficiency assessed as saleable seeds per spikelet and improved harvest index.

While the two closing dates were 10 to 13 days apart, the windrowing dates were only two and three days apart. This can be explained in part by the lower daily thermal time in October compared with the seed filling period of late December-January.

Conclusions

(1) Delaying closing from early mid-October to late October had a dramatic,

positive effect on seed yield of irrigated Italian ryegrass.

(2) The optimum TE rate was between 200 and 400 g/ha. The addition of CCC to TE did not consistently improve seed yield.

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