Ryegrass seed production in New Zealand: achieving 3000+ kg/ha yields

M.P. Rolston, R.J. Chynoweth, S.R. Vreugdenhil, and A.M. Gunnarsson
Foundation for Arable Research (FAR), 185 Kirk Road, Templeton, Christchurch, New Zealand
phil.rolston@far.org.nz

Abstract

Average ryegrass seed yields have increased from 800 to ~1,700 kg/ha over the 20 year period from 1992 to 2012. This paper reviews the key management changes and the under-pinning research and extension programmes that have driven this change. These changes include defining: optimum nitrogen (N) rates and timing, defoliation dates, fungicide products and timing, use of stem shortening plant growth regulators, and reducing seed loss at harvest. Optimum spring N requirements are ~172 kg N/ha (applied N and soil N). Plant growth regulator application can increase seed yield by up to 65% with optimal timing depending on flowering date. Closing date has been extended 10 to 14 days. Delayed closing in Italian ryegrass increased seed yields by approximately 1,170 kg/ha. Irrigation is used on over 80% of ryegrass seed crops and maintains seed yield potential in seasons of water deficit. Stem rust can result in seed yield losses of between 10 and 200%. Seed loss at harvest can contribute to yield losses of 20% of the saleable seed available at cutting. Disc mowers have gradually been replaced by windrowers potentially reducing losses by 190 kg/ha. Extension using field based meetings for growers and seed company field reps have been held every year at four locations to update research progress since 2006.

Additional keywords: extension, fungicides, harvest methods, nitrogen, trinexapac-ethyl

Introduction

Ryegrass seed production is mostly undertaken on the Canterbury plains and the down lands of South Canterbury and covers an average annual area of ~18,000 ha (Chynoweth *et al*., 2015). Production is mainly perennial ryegrass (*Lolium perenne* L.) both forage and turf (80% of area); with the remainder as either hybrid ryegrass (L. x hybridum Hausskn.) or Italian and annual ryegrass (*L. multiflorum* Lam). Ryegrass seed production is integrated into crop rotations with cereals, clovers, forage herbs or vegetable seed crops. There are over 120 cultivars grown of which most are proprietary cultivars. ‘Grasslands Nui’, a non-proprietary (common) perennial cultivar, mostly grown for export, represents ~20% of production and is a baseline to which head emergence and flowering dates of other cultivars are related. For example ‘Grasslands Nui’s’ flowering date is set at 0 days with proprietary cultivars ranging from ‘Grasslands Nui’ -5 days to ‘Grasslands Nui’ +32 days. Many crop management decisions, e.g. closing dates, are determined by growth stage, especially heading date. Again, ‘Grasslands Nui’ is often used as a reference point. Over the 20 year period from

1992 to 2012, average seed yields have doubled from 800 kg/ha to over 1700 kg/ha for all cultivars (Chynoweth *et al*., 2015). This paper reviews some of the factors that have helped drive this yield increase.

Nitrogen

Nitrogen (N) is the key macro-nutrient required to ensure an optimum seed head number and thus whether yield potential is achieved. Optimum seed head numbers range from 1,200/m^2 for annual ryegrass to 2,400/m^2 for turf type perennial ryegrass (FAR unpublished data). Autumn N either at establishment or post-emergence is typically 30 to 40 kg N/ha. Twenty eight field trials from 2003 to 2012 evaluated spring N rate responses and N uptake for maximum seed yields. The average optimum spring N requirement was 172 kg N/ha, including applied N + soil mineral N (NO_3^- and NH_4^+ in 0-30 cm soil layer) (FAR, 2013). The average applied N for optimum seed yield was 135 kg/ha (Table 1). Higher seed yielding crops (>2,300 kg/ha) did not require more N. A survey of seed growers in South Canterbury indicated average application rates were 221 kg N/ha during 2003 (Rolston *et al*., 2007). High N rates were associated with early lodging and lower seed yields (FAR unpublished data). Growers can delay lodging and produce higher seed yields where spring applied N (kg/ha) is calculated as:

Applied N (kg/ha) =

172 – soil mineral N (0-30 cm) kg/ha.

The traditional timing of spring N has been to apply N between the beginning of stem extension and head emergence (e.g. Brown, 1980; Hampton, 1987) with a more recent shift to applying all N within 2-3 weeks of closing (Rowarth *et al*., 1998). However with this approach, all N is applied before plant growth regulator application (PGR), which is usually 5 weeks after closing at Zadoks growth stage (GS) 32 (Zadoks *et al*., 1974). The current approach is to apply half the spring N at closing and half at or after PGR application, or later, demonstrated no negative seed yield effects and sometimes a yield benefit (Table 2).

Table 1: Perennial and hybrid ryegrass response to nitrogen (N) for 28 trials (FAR, 2013) including 11 trials with seed yield >2,300 kg/ha grown throughout Canterbury, New Zealand over the 2003 – 2012 growing seasons, ± the standard error of the mean (±SEM).

	All trials n=28	Seed yield >2300 n=11
Soil mineral N* (kg N/ha)	38 ±4	29 ±3
Optimum applied N (kg N/ha)	135 ±7	119 ±10
Optimum total N (kg N/ha)	172 ±8	148 ±9
Seed yield N 0 (kg/ha)	1480 ±82	1660 ±160
Seed yield N optimum (kg/ha)	2240 ±70	2610 ±70
Seed yield response (kg/ha)	760 ±71	950 ±149
kg seed/kg N applied	6.0 ±0.6	7.8 ±1.0

Table 2: Seed yield of perennial ryegrass, cv 'Grasslands Samson' when nitrogen (kg N/ha) was applied at closing (7 October), plus 3 weeks or closing plus 8 weeks when grown at, Greendale, Canterbury in the 2010/11 growing season.

Nitrogen application timing			Applied N*	Seed yield
Closing	+3 weeks	+8 weeks	(kg N/ha)	(kg/ha)
0	0	0	0	1060
80	80	0	160	1920
80	0	80	160	2470
			LSD 5%	223
			F.prob	<0.001

*Soil mineral N (0-30 cm) = 30 kg N/ha

Plant growth regulator response

Trinexapac-ethyl (TE) (original trade name Moddus®) is a stem shortening plant growth regulator introduced in the year 2000 and rapidly adopted as a management tool (Pyke *et al*., 2004). Compared with nil TE, seed yields typically increased by greater than 40% when appropriate rates were used (Chynoweth *et al*., 2010). The seed yield response has been attributed to an increase in the number of seeds produced per spikelet and changes in harvest index as a result of delayed lodging (Rolston *et al*., 2010a) and reduced reproductive stem length (Chynoweth and Moot, 2017). In early to mid-flowering date cultivars the optimum timing for TE application is Zadoks Growth Stage (GS) 32 (Zadoks *et al*., 1974). However, in late flowering cultivars there was an advantage with splitting applications of 800 g TE/ha, starting at GS 30-31 with a triple split being more effective than a single 800 g TE/ha application at GS 32 (Table 3) (Chynoweth *et al*., 2014). The split application response in late flowering ryegrasses (e.g. 'Grasslands Nui' +21 days) is attributed to the crop are undergoing stem elongation in warmer temperatures with higher solar radiation receipts and thus accumulating biomass more rapidly than early flowering cultivars.

In Italian ryegrass, seed yield increased by 65% (~800 kg/ha above the control) with a single application of 400 g TE/ha in late November (Trethewey *et al*., 2016). No further significant increases in seed yield were observed when rates were increased to 600 and 800 g TE/ha as either a single or split application, for Italian ryegrass closed late, i.e. 28 October – 4 November.

Closing date

Ryegrass seed crops are usually grazed or defoliated in early/mid spring. The date of the last defoliation is referred to as the 'closing date'. Traditional closing dates for 'Grasslands Nui' types were the 15th to 20th of September, at the start of stem elongation. Delayed closing results in removal of greater biomass thus reducing potential lodging with the potential to remove developing seed heads.

Table 3: Seed yield of perennial ryegrass, cv 'Base' when the plant growth regulator trinexapac-ethyl (TE) was applied at various rates and at up to three Zadoks growth stages (GS) when grown at Leeston, Canterbury in the 2016/17 growing season.

31-Oct GS.31	10-Nov GS.32	22-Nov GS.33	Seed Yield (kg/ha)
	TE (g/ha)		
0	0	0	1240
0	200	0	1890
0	400	0	2220
0	600	0	2380
0	800	0	2370
200	200	200	2440
267	267	266	2840
350	250	0	2560
		LSD 5%	268
		F.prob	<0.001

The removal of growing points in early tillers can be advantageous by helping to produce more uniform head emergence, allowing for more accurate prediction of growth stages for PGR application and harvest decisions (Rolston *et al*., 2010b). There was no yield loss when closing 'Grasslands Nui' flowering date types was delayed for 20 days after the 20th of September (Chynoweth *et al*., 2010). However in perennial ryegrass, closing too late removes a critical number of growing points and yield reductions can be expected. In many Italian ryegrass cultivars delayed closing from early to mid- October to late October has lifted seed yields by approximately 1,170 kg/ha as well as resulting in more grazing time (Table 4) (Rolston *et al*., 2012).

In late closed annual ryegrass there was no advantage from split applications of PGR (Heney *et al*., 2017).

Lower PGR rates are often required for cultivars closed later compared with cultivars that were closed earlier. For example, perennial ryegrass closed on the 25th September responded to increasing rates of TE up, to 800 g TE/ha, compared with maximum response at 600 g TE/ha for closing on the 5th October, and 200 g TE/ha for crops closed on 15th October (FAR, 2016).

Irrigation

We estimate that over 80% of ryegrass seed crops are grown with irrigation. In one study, (Chynoweth *et al*., 2012) the timing of water is less critical than the deficit the crop was exposed to. Generally irrigating to 66% of evapo-transpiration (ET) did not reduce seed yield compared to full ET replacement as rainfall was then utilised rather than leached. However, early water stress tended to reduce head number, while late water stress reduced thousand seed weight (TSW). Seed yield response to irrigation was 1.6 kg/ha per mm of applied water and a seed yield loss of 4.3 kg/ha/mm of deficit above 50 mm (Chynoweth *et al*., 2012) when grown on a shallow soil holding approximately 70 mm of plant available water.

Table 4: Seed yield (kg/ha) of annual ryegrass, cv 'Archie' when four rates of plant growth regulator trinexapac-ethyl (TE) were applied at two closing dates, grown at Wakanui, Canterbury in the 2009/10 growing season.

TE	Closing Date		
a(g/ha)	10-Oct	20-Oct	Mean
0	1510	2650	2080 b
200	2510	3380	2950 a
400	2330	3580	2960 a
600	2200	3630	2920 a
Mean	2140	3310	
	LSD 5%	F.prob	
TE	243	<0.001	
Closing date	153	<0.001	
TE x Closing	343	0.005	

Means followed by different letters are different at 5% significance level.

Disease management and fungicide use

Stem rust (*Puccinia graminis*) is the major yield limiting disease (Latch, 1980) and typically between two (New Zealand bred forages) and four (turf and European-bred forages) applications of fungicide are used for control. Seed yields are typically increased by 20% in forages and 40% in turf ryegrasses with fungicide applications (Rolston *et al*., 2009). There are a number of effective fungicides for stem rust control in the demethylation inhibitor (DMI or triazole group)), and quinol oxidation inhibitors (QoI) (strobilurin group) and new fungicides are still being released in the succinate dehydrogenase inhibitors (SDHI fungicide group) (Table 5). It is common for growers to either tank mix fungicide groups or alternate different groups in a sequence. Fungicides present two issues: (i) identifying fungicides that are safe to use on grasses containing endophyte (*Epichloë festucae* var. *lolii*) (Rolston and Agee, 2007); and (ii) the withholding periods for many fungicides (often 14 to 35 days) create potential difficulties when crop residue (straw) is sold for winter feeding of cattle, as a late fungicide applied during the seed fill period is often required.

Table 5: Seed yield of turf perennial ryegrass, cv 'Centurion' when fungicides were applied at various rates (L/ha) and timings when grown at Greendale, Canterbury during the 2017/18 growing season (FAR unpublished data).

31-Oct GS 32	30-Nov Head emergence	14-Dec Flowering	28-Dec +14	Seed yield (kg/ha)
0	0	0	0	2420
Proline[1] 0.4	0	0	0	2720
0	Proline 0.4+Comet[2]	Proline 0.4+Comet 0.8	0	3260
Proline 0.4	Proline 0.4+Comet	Proline 0.4+Comet 0.8	0	3300
0	Proline 0.4+SF[3] 0.6	Proline 0.4+SF[3] 0.6	0	3360
Proline 0.4	Proline 0.4+SF 0.6	Proline 0.4+SF 0.6	0	3330
0	Proline 0.4+SF 0.6	Proline 0.4+Comet 0.8	SF 0.6	3440
			LSD	303

[1]Proline® = prothioconazole 250 g/L DMI fungicide; [2]Comet® = pyraclostrobin 250 g/L QoI fungicide; SF = [3]Seguris Flexi® = isopyrazam 125 g/L SDHI fungicide.

Harvest and harvest losses

Harvest losses have been assessed by collecting seed in aluminium foil trays (7 cm x 12 cm) at each stage of the harvest cycle: (i) cutting, (ii) drying in the windrow or swath, (iii) during combine pick-up, and (iv) losses with straw in the offal row. Losses have also been assessed by vacuum sampling 0.50 x 0.50 m quadrats after harvest. Both these studies identified that harvest losses were large, averaging 20% of the saleable seed pre-cutting, and that the cutting process was the major cause of loss (Rolston and Chynoweth, 2010). The cutting losses were always high on the divide between the cut and uncut boundary, were the overlapping heads are separated in the dividing process. Losses were also high if rain events occurred during drying in the windrow/swath.

Disc mowing was a common cutting method up until early-2000s. Disc mowers are narrow, typically 2.5 m wide, and therefore more divides occur. Since then windrowing using either draper belts or auger windrowers has increased to the point where they are now the predominant cutting machine used. Windrowers are wider and therefore there are fewer divides. Lower seed losses were recorded in windrowed fields compared with disc mown crops (Table 6).

In the 2016/17 harvest, a new windrower front ('Legacy', John Deere) was first used in NZ. The 'Legacy' cuts at higher ground speed (15 km/h) compared with conventional windrowers that cut at 7 to 8 km/h. Aerodynamic foils in the 'Legacy' float the cut crop as it falls with supposedly less seed loss. Three large scale field trials in 2016/17 and 2017/18 using commercial cutting and farmer combines compared seed yields in ryegrass cut with the 'Legacy front' to that of a conventional windrower and a disc mower. Plots were at least 0.5 ha, and each treatment was duplicated. Seed yields were consistently higher in the 'Legacy' cut treatments by 240 kg/ha and 420 kg/ha for the windrow and disc treatments respectively (Table 6).

Table 6: Seed yield for a hybrid and two turf or perennial ryegrass cultivars cut with three different machines near Chertsey, Canterbury during the 2016/17 and 2017/18 growing seasons.

Cultivar	Year	Seed yield (kg/ha)		
		Legacy Windrower	Standard Windrower	Disc Mower
Shogun (hybrid)	2016/17	3200	2990	2640
DLF 46-600 (turf)	2017/18	3110	2830	n/a
Bokser (turf)	2017/18	2920	2680	2660
Average		3070	2830	2650
LSD 10%			210	

Ryegrass discussion groups

A key factor in developing changing grower practices in ryegrass has been the discussion group format started in 1994 under the banner of 'Ryegrass 2000' (Rolston, 1995) and later in 2004 the 'Ryegrass 3000' groups for growers and seed company field reps (Rolston *et al*., 2007). Field meetings are held every spring, usually in four locations and support remains strong 23 years on, with each meeting attended by between 20 and 40 people. A key take-home message to growers and seed company field reps was to understand the interaction between closing date, N timing and rate and PGR timing and rate. Getting any one of these components wrong usually results in early crop lodging and lower seed yield.

The highest seed grower paddock yield for forage perennial ryegrass was 3,990 kg/ha for cv 'Commando' at Rakaia (M. Kelly, PGG Wrightson Seeds, pers. comm), while the highest treatment yield in FAR plot trials in growers fields is 4,050 kg/ha for cv 'Bealey' at Wakanui (FAR Trial H1410). We believe average seed yields will continue to increase towards 3,000 kg/ha as growers continue to learn to how to balance the interactions between closing date, nitrogen timing and rates, and PGR timing and rates and managing harvest losses.

References

Brown, K.R. 1980. Seed production in New Zealand ryegrasses II. Effects of N, P, and K fertilisers. *New Zealand Journal of Experimental Agriculture* 8: 33-39.

Chynoweth, R.J. and Moot, D.J. 2017. Seed growth of three perennial ryegrass cultivars sown on two dates and treated with trinexapac ethyl straw shortener. *Grass and Forage Science* 72: 271-280.

Chynoweth, R.J., Rolston, M.P. and McCloy, B.L. 2010. Plant growth regulators. A success story in perennial ryegrass seed crops. pp. 47-58. *In:* Seeds for Futures, Proceedings of a joint symposium between the Agronomy Society of New Zealand and the New Zealand Grassland Association, 26-27 November 2008, Palmerston North, New Zealand.

Chynoweth, R.J., Rolston, M.P. and McCloy, B.L. 2012. Irrigation management of perennial ryegrass (*Lolium perenne*) seed crops. *Agronomy New Zealand* 42: 77-85.

Chynoweth, R.J., Trethewey, J.A.K., Rolston, M.P. and McCloy, B.L. 2014. Reduced stem length increases perennial ryegrass seed yield. *Agronomy New Zealand* 44: 61-70.

Chynoweth, R.J., Pyke, N.B., Rolston, M.P. and Kelly, M. 2015. Trends in New Zealand herbage seed production: 2004-2014. *Agronomy New Zealand* 45: 47-56.

Foundation for Arable Research. 2013. Nitrogen in perennial ryegrass seed crops. Foundation for Arable Research New Zealand Cropping Strategies, Issue 5 (Spring 2013), https://www.far.org.nz/assets/files/uploads/30178 FAR cropping strategy issue 5 –N in perennial ryegrass.pdf

Foundation for Arable Research. 2016. Closing date in perennial ryegrass; closing date in Italian ryegrass. Foundation for Arable Research New Zealand Cropping Strategies, Issue 6 (Spring 2016), https://www.far.org.nz/assets/files/blog/files//2c6f1d23-3c63-4bf7-8ed2-bb7b5543083f.pdf

Hampton, J.G. 1987. Effect of nitrogen rate and time of application on seed yield in perennial ryegrass cv. Grasslands Nui. *New Zealand Journal of Experimental Agriculture* 15: 9-16.

Heney, J.W.L., Rolston, M.P., Chynoweth, R.J. and McCloy, B.L. 2017. Seed yield response of annual ryegrass to stem shortening plant growth regulators. *Agronomy New Zealand* 42: 29-36.

Latch, G.C.M 1980. Importance of diseases in herbage seed production. pp. 36-40. *In*: Herbage Seed Production, Grassland Research and Practice Series No. 1. New Zealand Grassland Association.

Pyke, N.B., Rolston, M.P. and Woodfield, D.R. 2004. National and export trends in herbage seed production. *Proceedings of the New Zealand Grassland Association* 66: 95-102.

Rolston, M.P. 1995. Ryegrass 2000. pp. 296-297. *In:* Proceedings of the 3rd International Herbage Seed Conference, 18-23 June, Halle (Saale), Germany.

Rolston, M.P. and Agee, C. 2007. Delivering quality seed to specification: the USA and NZ novel endophyte experience. pp. 229-231. *In:* Proceedings of the 6th International Symposium on Fungal Endophytes of Grasses, 25-28 March 2006, Christchurch, New Zealand.

Rolston, P., Trethewey, J., McCloy, B. and Chynoweth, R. 2007. Achieving forage ryegrass seed yields of 3000 kg/ha and limitations to higher yields. pp. 100-106. *In:* Proceedings of the 6th International Herbage Seed Conference, 18-20 June, Gjennestad, Norway.

Rolston, M.P., McCloy B.L., Harvey, I.C. and Chynoweth, R.J. 2009. Ryegrass (*Lolium perenne*) seed yield response to fungicides: a summary of twelve years of field research. *New Zealand Plant Protection* 62: 343-348.

Rolston, M.P. and Chynoweth, R.J. 2010. Harvest loss in ryegrass seed crops. pp. 64-68. *In:* Proceedings of the 7th International Herbage Seed Conference, 11-13 April, Dallas, Texas.

Rolston, M.P., Trethewey, J.A.K., Chynoweth, R. and McCloy, B. 2010a. Trinexapac-ethyl delays lodging and increases seed yield in perennial ryegrass seed crops. *New Zealand Journal Agriculture Research* 53: 403-406.

Rolston, M.P., McCloy, B.L., Trethewey, J.A.K. and Chynoweth, RJ. 2010b. Removing early spring emerged reproductive growing points enhances seed yield of Italian ryegrass. *Agronomy New Zealand* 40: 133-139.

Rolston M.P., Trethewey J.A.K., Chynoweth R.J. and McCloy, B.L. 2012. Italian ryegrass seed yield: Trinexapac-ethyl and closing date interaction. *Agronomy New Zealand* 42: 119- 127.

Rowarth, J.S., Boelt, B., Hampton, J.G., Marshall, A.H., Rolston, M.P., Sicard, G., Silberstein, T.B., Sedcole, J.R. and Young, W.C. 1998. The relationship between applied nitrogen concentrations in herbage and seed yield in perennial ryegrass (*Lolium perenne* L.) I. Grasslands Nui at five sites around the globe. *Journal of Applied Seed Production* 16: 105-114.

Trethewey, J.A.K., Rolston, M.P., McCloy, B.L. and Chynoweth, R.J. 2016. The plant growth regulator, trinexapac-ethyl, increases seed yield in annual ryegrass (*Lolium multiflorum* Lam.). *New Zealand Journal of Agricultural Research* 59: 113-121.

Zadoks, J.C., Chang, T.T. and Zonack, C.F. 1974. A decimal code for the growth stages of cereals. *Weed Research* 14: 415-421.