Optimising Italian ryegrass sowing rates

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Abstract
Research by PGG Wrightson Seeds, Victorian Department of Primary Industries and others at plot and farm scale has demonstrates profits from drilled monocultures of annual ryegrass (*Lolium multiflorum* Westerwold) are maximized with sowing rates of approximately 40 kg Seed/ha, with additional seed generally providing yield benefits for the first two harvests only. Maximum yield occurs at approximately 50 kg/ha and the systems have a diminishing marginal return. In annual ryegrass, the benefits of changing from traditional to demonstrated optimum sowing rates is not trivial, in the order of $100/ha/year (seed and supplement cost dependent).

During 2013 and 2014 PGG Wrightson Seeds undertook sowing rate response experiments on four Italian ryegrass cultivars (*Lolium multiflorum*) with rates between 5 and 80 kg seed/ha. Yield was determined over five and four harvests in 2013 and 2014 respectively. Yield was found to be linearly correlated with sowing rate at the first harvest and the yield of different sowing rates had generally converged by the third harvest. This confirms sowing rate manipulates autumn and/or winter growth rates in Italian ryegrass. Total yield was well modeled by a polynomial (average r^2=0.58) with maximum yield occurring at approximately 60 kg seed/ha.

Assuming seed costs $6/kg, marginal cost analysis indicates profits are maximised at 38 kg seed/ha and 42 kg Seed/ha for a feed value of $200/tonne and $250/tonne respectively. For feed values of $200/tonne and $250/tonne, additional profits of $76/ha and $133/ha respectively can likely be achieved over a 15 kg seed/ha sowing rate.

Key words
Marginal cost analysis, seedling rate, yield response, winter pasture

Introduction
State and private sources generally advise that Italian ryegrass sowing rate should vary with rainfall of the target environment on the premise that low rainfall environments support fewer plant numbers. Recommended sowing rates range from 10 kg Seed/Ha to 30 kg Seed/ha with recommendations usually being environment or ploidy dependent (DPIWE, 2006 and Industry and Investment, 2010).

Research demonstrates that winter yield of both annual (Venuto et al 2004 and DPI, 2007 & 2008) and Italian (Wynn, Hodgson and Andrews, 2011) ryegrass increases with sowing rate, but that this has little effect on spring yield. However, use of ANOVA to compare total yields instead of regression to model observed responses meant defensible sowing rate recommendations were not inferred from these works. Harmer, Sewell and Salmon (2012) presented more data and formalized it into a decision making tool based on marginal cost analysis using fitted response functions. This analysis demonstrates profit increases with sowing rate up to approximately 40 kg seed/ha in annual ryegrass, assuming seed and additional yield is worth $3.6/kg and $150/tonne respectively.

Wynn, Hodgson and Andrews (2011) suggests similar responses to those observed in Annual ryegrass also occur in Italian ryegrass, i.e. yield increases with sowing rate and there is a diminishing marginal return. This study aims to confirm the yield response of Italian ryegrass to sowing rate with a series of trials, and determine optimal sowing rates based on this data.

Method
The trials were drill-sown into prepared seed beds at the PGG Wrightson Seeds Research Farm at Leigh Creek (-37°56'S, 143°95'E), south-western Victoria. The soil is a deep red Krasnozem weathered in-situ

from basalt. The 2013 trials utilised diploid (cv. Knight) and and tetraploid (cv. Feast II and Shogun) Italian ryegrasses and the 2014 trial used a diploid Italian ryegrass (cv. Concord II). Trials were planted in the Autumn (11 April 2013 and 17 April 2014) with a starter fertiliser (44 kg N/ha) applied at the two leaf stage. Trials were fertilised to replace N post-harvest with all other nutrients non-limiting.

The 2013 trial had two replicates of the sowing rates 10, 20, 30, 40, 50 and 60 kg seed/ha and was a randomised complete block design. The 2014 trial was a completely randomised design with a single entry of rates between 5 and 80 kg seed/ha in 5 kg seed/ha increments, i.e. 16 plots. Yield was determined in both trials by full plot harvest of all forage above 50 mm from ground level and the collection of sub samples for dry matter determination. The 2013 trial was harvested five times between 31 July and 11 November 2013 and the 2014 trial was harvested until it could be confidently demonstrated that high sowing rate benefits had disappeared; this required four harvests between 26 August and 4 October 2014.

Results

Figure 1 presents results of the 2013 trial as the mean response of cv. Knight, Feast II and Shogun at each of the five harvests. Figure 2 presents results for the 2014 trial (cv. Concord II only). Results for harvest three of the 2014 trial are unavailable. Based on evidence from the second harvest of this trial (where no response occurred), all previous trials and literature, it is reasonable to assume no response to sowing rate occurred at this third harvest. The absence of this data (given no response was expected) does not affect the recommendations or conclusions of this work. ASReml (VSN International, 2014) was utilised to account for spatial variation in the 2013 data set with treatment fitted as a fixed affect. The 2014 trial layout did not allow spatial analysis, accordingly Figure 2 presents raw data.

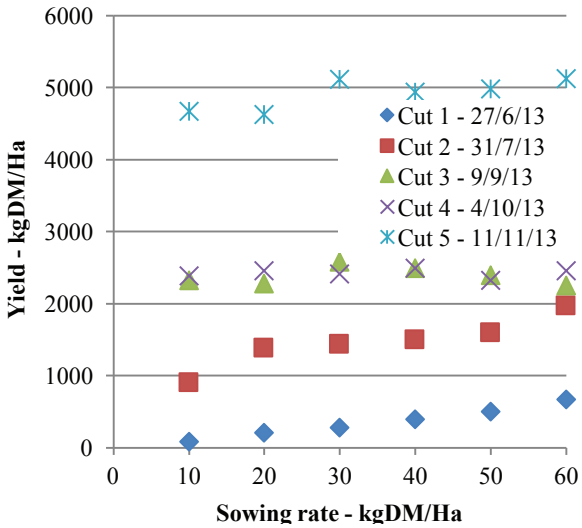

Figure 1. Results from the 2013 sowing rate trial, mean of cv. Knight, Feast II and Shogun at each harvest.

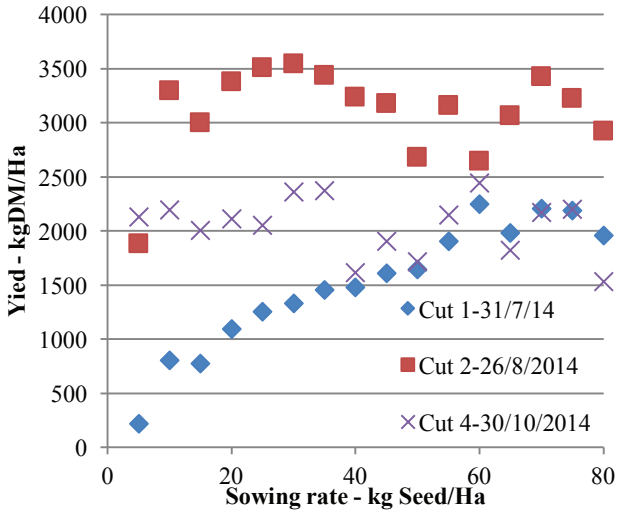

Figure 2. Results of the 2014 sowing rate trial, cv. Concord II only at each harvest.

The affect of sowing rate at each harvest was assessed using linear regression. In 2013, sowing rate of Italian ryegrass significantly effected yield at the first ($p<0.0001$) and second ($p<0.001$) harvests but did not significantly affect yield at later harvests. In 2014, sowing rate affected yield at the first ($p<0.0001$) harvest only.

Previous research has shown that short term ryegrass yield response is well described by a polynomial response function in the sowing range investigated (Harmer, Sewell and Salmon 2012). Table 1 presents polynomial model parameters for total yield (the sum of all harvests) of each individual cultivar and an all cultivar function (see discussion).

Table 1. Summary of model parameters for polynomials fitted to individual cultivars
Significance levels: ***P<0.001; **P<0.05, *P<0.1

Cultivar	Constant	Sowing Rate	Sowing Rate^2	R-Squared
Concord II	8,163***	79.60**	-0.68*	0.52
Knight	9,200***	86.70	-0.67	0.61
Feast II	10,090***	64.45*	-0.52	0.73
Shogun	9,868***	76.65**	-0.46	0.87
All cultivars	-	84.75***	-0.72**	0.58

The constant component of the polynomial response is of no consequence for a marginal cost analysis based sowing rate decision. It is only change in yield (which occurs in winter) from one sowing rate to another (as described by the linear and quadratic coefficients in Table 1) that influence the recommendation.
As such, cultivar curves were standardized by subtraction of a cultivar's respective constant from each cultivar's respective total yield at each sowing rate, allowing data from all cultivars to be combined into a cultivar non-specific response function (Figure 3 whose parameters are in Table 1). This allows us to observe the mean affect of altering sowing rate in isolation from affects such as length of the season etc.

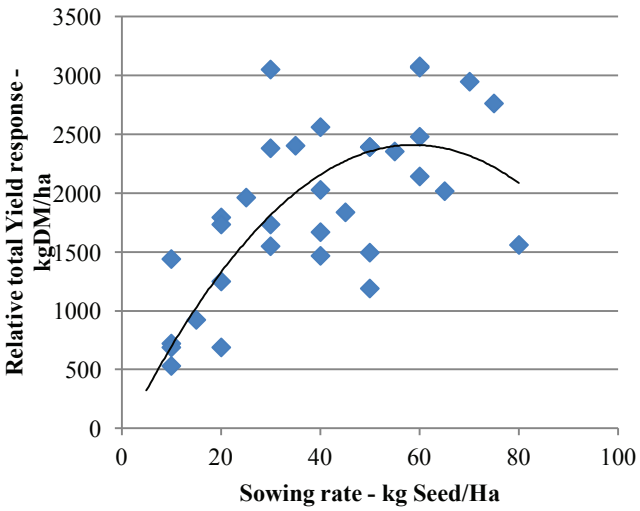

Figure 3. Relative yield response, all cultivars

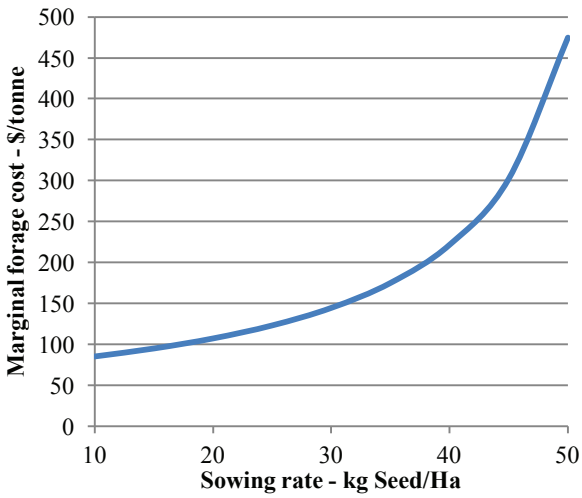

Figure 4. Marginal cost as a function of sowing rate

Discussion and conclusion

Consistent with all previous studies, yield at the first harvest was essentially a linear function of sowing rate and benefits of the higher sowing rate declining or disappearing altogether at later harvests (Figure 1 and 2), presumably due to compensatory tillering at the lower sowing rates. In affect, the higher sowing rate allows maximum production to be brought forward in time. Interestingly, the coefficient for the quadratic component of the cultivar specific function (Table 1) is generally not-significant. Only when they are combined into an "All cultivar" response does the quadratic coefficient become significant.

Figure 3 indicates yield can change by approximately 1,385 kg DM/ha from 15 kg seed/ha to a maximum at approximately 60 kg seed/ha. To make a rational sowing rate decision, the derivative of the "All Cultivar" response equation must to transformed by the inclusion of seed cost (assumed to be $6/kg seed) to a marginal cost curve [$\$/tonne = \left(\frac{1000}{-1.44 \times sowing\ rate + 84.75}\right) \times 6$] see Figure 4.

Whilst all farms will have a different marginal feed cost in mid-winter (Chapman, Kenny and Lane, 2013) when the yield response occurs, if we assume grass grown mid-winter is worth $200/tonne or $250/tonne, it can be seen from Figure 4 that a sowing rate of 38 kg seed/ha or 42 kg seed/ha respectively maximises profits in a monoculture.

Table 2 is provided to highlight the rationale of this recommendation for those unfamiliar with the logic of marginal cost analysis (for an agriculture focused introduction to the concept see Malcolm, Sale and Egan, 1996). Table 2 assumes additional yield is worth $200/tonne and additional seed is costs $6/kg. In the

"Yield" column, the average constant of all cultivars has been added to the "All Cultivars" response function presented in Table 1, thus *Total yield= -0.72×sowing rate^2+84.75×sowing rate+9330*. A diminishing marginal return can be seen in the declining marginal response of yield to subsequent 5 kg seed/ha increases in sowing rate. For sowing rate increases up to approximately 40 kg seed/ha the increase in revenue (due to a reduction in supplementary feed costs) more than offsets the increase in seed cost. As such sowing rate increases up to this point increase profit. Increasing sowing rates beyond this point is not rational as the additional seed cost is more than the value of additional yield grown.

Table 2. Mean effect of change in sowing rate on yield, costs, revenue and profit, assuming seed costs $6/kg and additional yield is worth $200/tonne.

Sowing rate	Yield	Change in yield from lower sowing rate	Change in costs from lower sowing rate	Change in revenue from lower sowing rate	Change in profit from lower sowing rate	Cumulative change in profit from 15 kg seed/ha
kg seed/ha	kg/ha	kg/ha	$/ha	$/ha	$/ha	$/ha
15	10,439	-	-	-	-	-
20	10,737	298	30.0	59.6	29.6	29.6
25	10,999	262	30.0	52.4	22.4	52.0
30	11,225	226	30.0	45.2	15.2	67.2
35	11,414	190	30.0	38.0	8.0	75.2
40	11,568	154	30.0	30.8	0.8	76.0
45	11,686	118	30.0	23.6	-6.4	69.6

Using high seeding rates in mixed swards has not been investigated but would likely result in clover being outcompeted, as such it is unadvisable. However, the responses identified in this research may present an opportunity for producers sowing mono-cultures to increase per hectare profit. These findings suggest research is warranted to determine how far sowing rates can be increased in a mixed sward before clovers are compromised.

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