Managing whole crop cereal silage yield and profitability of autumn-sown crops

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Abstract

Whole crop cereal silage is a high carbohydrate-low protein feed supplement for dairy cows that provides a balanced diet with pasture. For cereal silage to be a viable option for the grower, planting decisions should be designed to optimise dry matter production while remaining profitable. Autumn-sown experiments were run in the 2013-14 and 2014-15 seasons in Canterbury to determine management effects on biomass yield across different crop species (wheat, barley, oats, and triticale). Treatment combinations relating to planting decisions in first season included cereal species, cultivar, and sowing date and the latter was replaced with growth regulator treatments in the second season. All yield results were compared at a target harvest of 38% whole crop dry matter (DM) content. Triticale and wheat generally yielded higher than barley. Within species, later maturing cultivars performed the best in the 2013-14 trial, but no differences were found in 2014-15 between the five wheat cultivars tested. No yield advantage was seen with a 12 April sowing compared with those sown 16 May. When making planting decisions it was important to consider harvest date and the profitability within the rotation. Accepting a lower yielding crop that is harvested earlier than a high yielding crop that matures later can still be profitable as sowing date of the following crop becomes important in the context of the whole system. Generally, whole crop silage yield response to management decisions was consistent with strategies for increased grain yield, but results from these trials show there is opportunity to further manipulate for forage dry matter production while enhancing profitability.

Additional keywords: barley, oats, triticale, wheat, gross margins, nitrogen fertiliser, plant growth regulators, sowing date

Introduction

The demand for supplementary feeds is growing along with the growth of the dairy industry (Stevens *et al.*, 2004). Conserved supplements are useful in times of pasture shortage or for supplementing crops such as kale for winter feeding (de Ruiter *et al.*, 2007). Cereal production for feed use on dairy farms has occurred at various levels. For example, silage is often supplied under contract from cropping farmers to dairy users, or crops may be fully integrated on dairy platforms. There is an opportunity for the arable industry to produce more feed crops, such as cereal silage, if the quality and timing of production fits within farm systems and is economic for both the cereal silage producer and users of the crop.

Advances in cereal agronomy have resulted in significant improvements in grain production (Millner and Roskruge, 2014) from both autumn and spring-sown crops. The agronomic principles for achieving good establishment and high crop yields for silage are well established (de Ruiter and Hanson, 2004). However, there may be opportunities to further increase the area grown and improve yield by selecting appropriate cultivars and sowing dates. Compared with spring sowings, autumn-sown crops have a higher yield potential because of longer growth durations from sowing to harvest (Hughes and Haslemore, 1984). Autumn sown crops are usually harvested at an earlier date than spring-sown crops. This creates an opportunity to establish the next crop earlier and achieve a higher annual production. Relative performance of current cultivars are evaluated in FAR trials (FAR, 2015) for differing sowing dates and locations, but specific management options such as N fertiliser (FAR, 2013) and irrigation (FAR, 2010) practices may help growers achieve higher yield outcomes.

Trials on whole crop cereal silage have primarily focused on spring-sown crops in recent years (de Ruiter *et al.*, 2013). Trials in the 2001-02 (de Ruiter *et al.*, 2002; FAR, 2002) and 2011-12 (FAR, 2012) seasons compared cereal species and cultivars in spring-sown crops in Canterbury, but little research was done to determine causes for yield differences or how yield could be manipulated with agronomic treatments. The aim of autumn-sown trials in 2013-14 and 2014-15 was to determine whether yield advantages of sowing early were economic and whether species, cultivar selection or autumn sowing date had a significant effect on maturation date and suitability for silage.

Materials and Methods

Whole crop silage trials were established in autumn of 2013-14 and 2014-15 at the New Zealand Institute for Plant & Food Research Limited, Lincoln, New Zealand (43° 37' S, 172° 28' E). The soil was a Templeton silt loam (Typic Ustrochrept, USDA soil taxonomy). Both trials were irrigated to near field capacity when soil water deficits reached approximately 50 mm in the top 800 mm depth. All treatments imposed are given in Table 1. Dry matter production and crop duration were considered key variables in the assessment of trial entries and for determining the profitability of the crops.

2013-14 Autumn trial

A split-plot trial was sown on two dates (12 April and 16 May) in autumn of 2013. Sowing date comprised the main plots and factorial combinations of cultivar and nitrogen rate were completely randomised within the main plots. Entries comprised two wheats (cvs Wakanui and Morph), three barleys (two-row cvs Tavern and Retriever and six-row cv. 205-14) and a single triticale (cv. Prophet). These were grown at low N (150 kg N/ha) and high N (250 kg N/ha) rates. Wakanui and Morph were chosen primarily on their differing phenology with Wakanui being later maturing than Morph. Similarly, Retriever was chosen as a later maturing barley to compare with Tavern. Plot size was 10 x 1.95 m.

Previous crops on the site were potatoes (2009), oats (2010), barley (2011) and ryegrass (2012). The land was prepared by spraying out the ryegrass with 3 l/ha Roundup® (360 g/kg glyphosate) and 15 g/ha Granstar® (750 g/kg tribenuron-methyl) on 30 March. A pre-season soil test was collected on 30 March (Table 2). The seedbed was prepared by ploughing and Cambridge rolling on 1 April, followed by power harrowing and rolling twice on 10 April. A pre-emergence herbicide comprising Cougar (100 g/l diflufenican) at 1 l/ha plus Glean (750 g/kg chlorosulphuron) at 15 g/ha in 200 l/ha of water was applied over first sowing date plots on 16 April, and on 17 May for the late sown plots. To combat disease pressure, the whole trial was sprayed with 600 ml/ha Proline® (250 g/l prothioconazole) and 40 ml/ha Karate® (250 g/l lambda-cyhalothrin) on 14 August. Similarly, 1 l/ha Opus® (125 g/l epoxiconazole) and 40 ml/ha Karate® were applied on 9 September and again on 26 September over the whole trial. A final application of Opus and Amistar® (500 g/kg azoxystrobin) at 500 ml/ha each was sprayed on 11 November on all plots. Plant growth regulators (PGR's) were applied as general management to all trial entries to control stem elongation and reduce lodging. This comprised Cycocel® at 750 ml/ha (750 g/l chlormequat) and 250 ml/ha Moddus® (250 g/l triexapac-ethyl) on 6 September for the first sowing date and 11 October for the second sowing date plots.

Sowing rate for all cultivars at both sowing dates was based on a desired plant population of 200 plants/m^2. At sowing, 200 kg/ha of sulphur super 20 (0:8:0:21 N:P:K:S) was applied to all plots. A basal N rate of 50 kg N/ha was applied to all plots in the spring due to low soil N shown in mid-season soil tests after a wet winter (Table 2). Additional N treatments were split into early and late applications of 50 kg N/ha each time for the low N and 100 kg N/ha for the high N rate. Application dates for the first sowing date were 6 September and 24 September, and 24 September and 21 October for the second sowing date. All side dressings of fertilizer were applied as urea by hand.

Table 1: Experimental treatments for cereal silage trials.

Treatment	2013-14 Trial	2014-15 Trial
Sowing date	12 April, 16 May	7 May
Species (Cultivars)	Barley (205-14, Tavern, Retriever) Triticale (Prophet) Wheat (Morph, Wakanui) -	Barley (Sanette) Triticale (Prophet) Wheat (09-25, 12-45, Torch, Raffles, Wakanui) Oats (Coronet)
N rates	150 kg N/ha, 250 kg N/ha	-
Plant growth regulators (PGR)	-	Control: 2.0 l/ha CCC + 0.4 l/ha Moddus applied to triticale at GS30-31; nil applied to other species + PGR: 2.0 l/ha CCC + 0.4 l/ha Moddus applied to all species at GS30-31; 0.2 l/ha Moddus applied at GS 32 to triticale; 1.0 l/ha Terpal applied to barley at GS 37–39

Table 2: Soil minerals and mineral N for pre- and mid-season soil tests at the trial sites in Lincoln.

Sampling date	Depth (cm)	pH	P (mg/l)	K (QT)	Ca (QT)	Mg (QT)	Na (QT)	Sulphate S (mg/kg)	NH_4-N (kg N/ha)	NO_3-N (kg N/ha)	Total Mineral N (kg N/ha)
2013-14 Trial											
27 March 2013 (Pre-winter)	0-30								7.2	19.5	26.7
	30-60								5.4	2.4	7.8
	60-90								2.7	1.5	4.2
5 April 2013	0-7.5	6.0	17	6	10	13	8	5			
8 August 2013 (Mid-season)	0-15								1.6	9.6	11.2
	15-30								2.5	10.8	13.3
	30-60								3.9	4.7	8.6
2014-15 Trial											
2 April 2014	0-15	5.9	22	8	9	12	8	4			

2014-15 Autumn trial

The 2014-15 trial was sown on 7 May 2014 in a split plot design with cultivars as main plots and PGR's as subplots. Treatments comprising cultivar and PGR combinations were replicated 4 times. Wheat cultivars were Wakanui, Raffles, Torch, 09-25 and 12-45. These were selected to cover a range of maturities and plant heights. The wheat cultivars were compared against each other, and against forage oat (Coronet), spring barley (Sanette) and triticale (Prophet). Plot size was 10 m x 1.35 m.

'High' and 'low' PGR treatments were randomised within paired plots for each trial entry. Growth regulators were applied as Cycocel® (750 g/l chlormequat) and Moddus® (250 g/l triexapac-ethyl) and Terpal® (305 g/l mepiquat chloride and 155 g/l chlorethephon). Timing and concentrations of PGR chemicals are given in Table 1. Treatment inputs were selected specifically for each cereal species to represent the 'high' and 'low' PGR levels.

The trial site was previously in barley (2009), brassica (2010), barley (2011) and ryegrass from 2012. The ryegrass was sprayed out using Roundup® (4 l/ha) plus Granstar® (20 g/ha in 200 l/ha of water) on 3 April 2014. The site was ploughed them Cambridge rolled, then power harrowed on 1 May. On 7 May, 200 kg/ha of CropZeal 16N® (15.4:8:10:9.6 N:P:K:S) was spread on the whole site and seed sown. A pre-emergence herbicide comprising Cougar® (1 l/ha) plus Glean® (15 g/ha) in 200 l/ha of water was applied to all plots except the oats. Pre-season soil testing was undertaken on 2 April 2014 (Table 2). All trial entries had emerged by 3 June 2014. Banvel (200 g/l dicamba) at 500 ml/ha plus MCPA (375 g/l) at 2 l/ha was applied to oats on 28 July 2014. The trial was sprayed with Karate® (40 ml/ha in 200 l/ha of water) on 16 June. Barley plots were sprayed with 40 ml/ha of Karate® + 200 ml/ha Proline®, and wheat with 40 ml/ha of Karate® alone on 16 August and 25 August, respectively.

Measurements

Meteorological data were recorded on-site for both trials with a Campbell CR10X (Logan, Utah) datalogger equipped with LiCor200X pyranometer, Campbell 107 thermistors and tipping bucket rain gauge. This data was supplemented with long-term data collected from the Lincoln, Broadfields NIWA weather station located adjacent to the trial site. A summary of rainfall, temperature and radiation for the growing period are shown in Figure 1. In both trials, the date of awn tip appearance (GS49) was recorded for all treatments and percent dry matter (%DM) was determined at weekly intervals on replicates 1 and 3 only, and used as an indicator for scheduling main harvests. The %DM was determined by cutting approximately 30 stems at 5 cm above the ground from a pre-defined plot area. Samples were dried at 90°C until they reached a constant weight. Quadrat harvests for yield were taken when plots reached 38% DM for each treatment. The size of quadrat was 0.1 m^2 for the 2013-14 trial and 0.5 m^2 in the 2014-15 trial.

Data analysis

Data were analysed using ANOVA using GenStat (16th Edition, VSN International Ltd, UK). Treatment differences were compared using 5% Least Significant Difference (LSD). Checks were made for distribution of residuals and for homogeneity of variances. Gross margin per hectare per day was used to compare the profitability of crops over duration from sowing to silage harvest (38% DM). Gross margins were based on a value of 25 c/kg DM to determine total income. The gross margin per ha per day was calculated using duration from sowing to attainment of 38% DM for each plot and the yield achieved in each plot.

The gross margins for each trial entry accounted for actual costs incurred during the 2013-14 season. For relativity, the same costs for crop production were applied in both 2013-14 and 2014-15 seasons. Expenses for cultivation, sowing and harvesting were based on standards reported by Askin and Askin (2012). The cost of irrigation (115 mm in 2013-14, and 140 mm in 2014-15) was $1.40 per mm applied. Harvesting costs were assumed to be 4 c/kg DM and no allowance made for land costs.

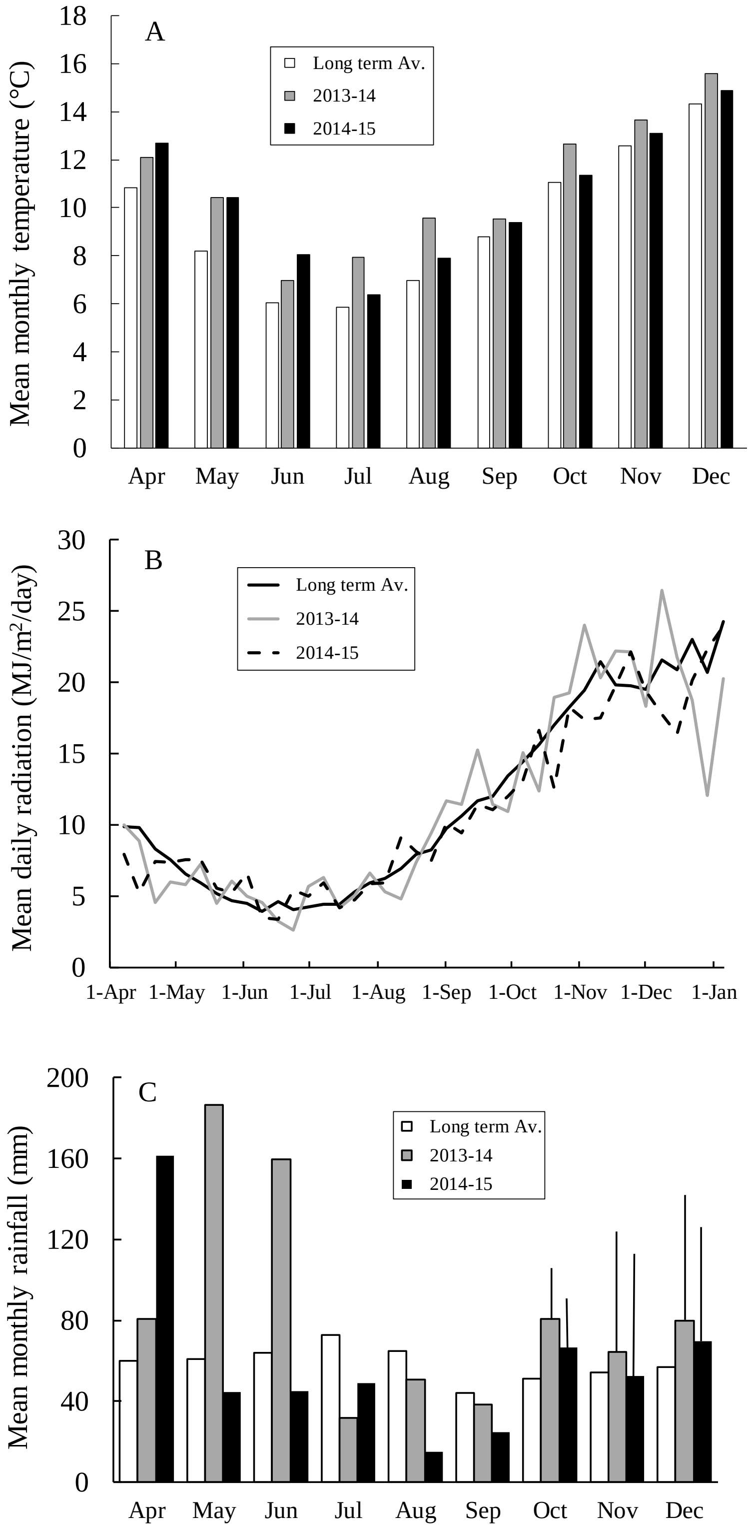

Figure 1: Mean monthly temperature (A), mean weekly radiation calculated from daily averages (B) and accumulated monthly rainfall (C) during the 2013-14 and 2014-15 growing seasons compared with the long-term average for Lincoln. Irrigation is indicated by vertical bar in C.

Table 3: Means for whole crop yield in response to sowing date, species and cultivar for cereal silage harvested at 38% DM in 2013-14.

Species/cultivar	Treatments	Yield (t DM/ha) 12 April sowing	Yield (t DM/ha) 16 May sowing
Barley mean		15.3	16.1
205-14		18.4	16.9
Tavern		10.4	13.5
Retriever		16.9	16.6
Triticale Prophet		28.4	25.5
Wheat mean		22.6	23.0
Morph		20.1	22.2
Wakanui		25.1	23.9
	Sowing date mean	19.9	19.6
	Nitrogen fertiliser		
	150 kg N/ha	20.1	17.9
	250 kg N/ha	19.7	22.2

Treatment effects	P-value	$LSD_{(0.05)}$
Species	<0.001	3.0
Cultivar	<0.001	2.54
Sowing date	0.602	1.89
Sowing date x N	0.093	2.57

Results

Main effect means for sowing date, species and cultivar are presented unless significant interactions occurred with nitrogen (2013-14) or plant growth regulator (2014-15).

Sowing date

There were no yield differences between crops at 38% DM when sown on 12 April or 16 May (Table 3). However, there was a marginally significant interaction between sowing date and nitrogen rate (P=0.093). Averaged over all cultivars, the earlier sown plots yielded 19.7 t/ha where 250 kg N/ha was applied and 20.1 t/ha where 150 kg N/ha was applied. Early-sown crops grew through a period of high winter rainfall, especially in 2013-14 and showed symptoms of N deficit in early spring. Late-sown crops appeared to be more responsive to N application rate than early-sown crops (Table 3) and these effects were carried through to yield differences at silage harvest. Some of the apparent increase in yield for the late sowing may have been caused by effective utilisation of N applied at the higher rate at a time when mean air temperatures were around 12°C (Figure 1B).

Species and cultivars

Differences in yield of cereal species occurred in both 2013-14 and 2014-15 trials (Table 3 and 4). There were no interactions between cultivar and other treatment effects apart from those mentioned above. Therefore, results are averaged for all main effects tested. In 2013-14 triticale produced the highest mean yield at 27.0 t/ha followed by wheat (22.8 t/ha) and barley (15.7 t/ha). There were yield differences (P<0.001) between cultivars within species in 2013-14 but not in 2014-15. Within the 2013-14 wheats, the later maturing Wakanui yielded 3.4 t/ha more than the earlier maturing Morph. Similarly, in barley, the later maturing Retriever and the six-row cultivar (205-14) produced higher yields than the early maturing Tavern.

In the 2014-15 trial, triticale and wheat again yielded the highest, with significant (P=0.033) differences between the species. No yield differences were observed within wheat cultivars in 2014-15 despite having been chosen for a range of maturities. However, there were differences (P=0.006) in the rate of growth during the period GS39-GS86. The later maturing cultivars (Wakanui, Torch and 12-45) had higher mean daily DM change over that period compared with the earlier maturing cultivars (Raffles and 09-25).

Table 4: Effect of species and cultivar on mean yield at silage harvest (38% DM) and growth rate between flag ligule and ears fully emerged in 2014-15.

Species	Cultivar	Yield (t DM/ha)	Growth GS39 to GS86 (kg DM/ha/day)
Oats	Coronet	19.5	263.8
Barley	Sanette	19.9	259.4
Triticale	Prophet	23.2	342.3
Wheat mean		21.4	319.7
	09-25	20.0	274.7
	12-45	22.1	328.9
	Raffles	21.6	302.4
	Torch	22.3	335.6
	Wakanui	20.8	357.1
Treatment effects			
P-value	Species	0.033	<0.001
	Species x Cultivar	0.353	0.006
$LSD_{(0.05)}$	Species	2.0	32.7
	Species x Cultivar	NS	42.2

Table 5: Total revenue, gross margins and margin per hectare per day for silage crops grown in 2013-14 and 2014-15.

	Wheat[a]			Two-row barley[a]			Triticale			Six row barley		Oats
Sowing Date	12 April 2013	16 May 2013	7 May 2014	12 April 2013	16 May 2013	7 May 2014	12 April 2013	16 May 2013	7 May 2014	12 April 2013	16 May 2013	7 May 2014
Duration (d)	257	240	235	224	215	219	248	233	226	245	228	236
Yield (t DM/ha)	22.6	23.0	21.4	13.7	15.1	19.9	28.4	25.5	23.2	18.5	16.9	19.5
Return ($/ha)	5,648	5,703	5,340	3,418	3,597	4,975	7,111	6,746	5,800	4,613	4,413	4,881
Expenses ($/ha)	2,577	2,104	2,521	2,204	1,926	2,534	2,809	2,240	2,669	2,314	1,962	2,499
Margin ($/ha)	3,071	3,599	2,819	1,213	1,671	2,436	4,303	4,506	3,131	2,298	2,451	2,383
(c/kg)	13.5	15.7	13.2	8.1	11.0	12.2	15.1	16.8	13.5	12.4	13.9	12.2
Margin ($/ha/day)	12.0	15.2	12.0	5.2	7.8	11.1	17.3	19.5	14.5	9.4	10.8	10.1

[a] Mean of cultivar entries within sowing date x year.

Gross margins

In 2013-14, early-sown cultivars producing high yield also had higher expenses covering the range of $2,000-$2,900 per ha. Wheat and triticale were more costly crops to grow but had higher mean yield at 22.6 and 28.4 t/ha. Although cheaper to grow, two-row barley had low yield (mean 13.7 t/ha). For later sown crops, all cultivars were produced with similar expenses (mean $1,640/ha) though there were differences in the mean yield of wheat, triticale and two-row barley (23.0, 25.5 and 15.1 t/ha respectively). Margins calculated as $ per ha for cultivar means showed a range of $1,213 to $4,506 (Table 5). Triticale invariably gave the best profit (mean $3,980/ha at 15.1 c/kg) followed by wheat ($3,163/ha at 14.1 c/kg), then oats ($2,383/ha at 12.2 c/kg) and two-row barley ($1,773/ha at 10.4 c/kg). Overall, there was a close relationship between yield and profit (R^2=0.88 when profit was expressed as $/ha and R^2=0.52 when profit was expressed as c/kg DM).

Profitability - gross margin/ha/day

The duration the crop is in the ground and the yield gained can influence crop profitability as defined by the marginal cost per hectare per day (Table 5). High producing crops grown over a short period will therefore be most profitable. In both seasons, marginal profitability was strongly driven by yield (Figure 2), and more importantly, by the cultivar selection. Sowing date influence the marginal profitability (Figure 2), primarily because there were additional costs with early sowing. However, there did not appear to be any differences in marginal profitability driven by in-season agronomic treatment e.g. nitrogen fertiliser rate (2013-14) or application of growth regulator (2014-15). The highest marginal profitability was achieved by triticale with an average of $14.5-$19.5/ha/day, compared with wheat at $12.0-$15.2/ha/day, followed by two-row barley at $5.2-$11.1/ha/day from sowing to 38% DM harvest.

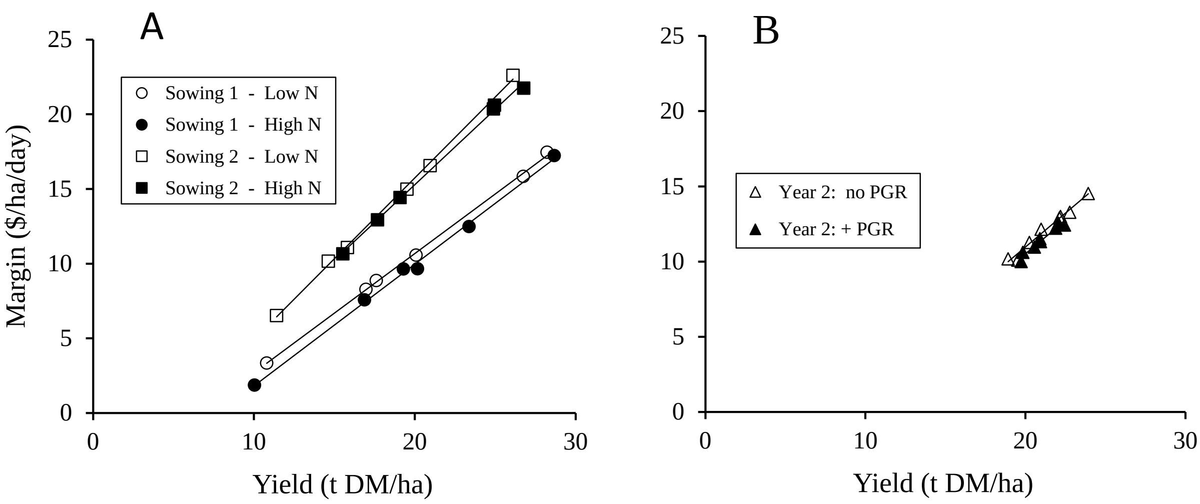

Figure 2: Margins ($/ha/day) for crop entries in 2013-14 (A) and 2014-15 (B) trials showing sowing date, nitrogen and growth regulator effects.

Discussion

A yield advantage with an earlier sowing date was expected based on trends in recent cultivar performance trial results (FAR, 2015), but this was not confirmed in this study when comparing 12 April and 16 May sowing dates. In other FAR sowing date trials Craigie (2014) also found little advantage with early autumn sowing. The benefits of early sowing may only be realised if growth conditions are favourable for rapid establishment and early growth. In this trial, establishment conditions for plots sown 12 April 2013 were not considered favourable for establishment with 179 mm of rainfall occurring between 12 April and the later sown 16 May plots. However, there was an indication of final yield enhancement in early-sown crops fertilised with high (250 kg N/ha) rates compared with 150 kg N/ha. In May and June 2013, above average rainfall possibly contributed to high N leaching losses below the rootzone. Additional nitrogen fertiliser was required in early spring to offset an observed deficiency in both early and late sowings. If there are no consistent yield losses from later establishment, then a later sowing gives the grower more flexibility to ensure conditions are right for sowing, and ensures that profitability defined as biomass production (kg DM//ha/day) is maximised. This measure of production efficiency is increased by shortening the number of days the crop is in the ground, and also allowing more flexible timing of crop utilisation in grazing systems for summer-sown crops intended for late autumn use. Moreover, the differences in silage harvest date (data not shown) were not greatly different between early and late sowing. Data not shown here supports earlier research (de Ruiter *et al.*, 2002; 2013) that timing at harvest is a much more important consideration in terms of ensuring high silage yield and high quality.

As expected, there were significant yield differences between the cereal species in both seasons. High yields from triticale were expected based on previous studies (de Ruiter *et al.*, 2002; FAR, 2012), but yields from wheat and barley of around 3-4 t DM/ha less than triticale were considered acceptable especially if high feed quality was achieved. Trials in both years confirmed the importance of cultivar selection for maximising crop production (quality data not shown) and profitability. In 2014-15, there was little difference between the wheat cultivars and this was possibly due to the selection being made on plant characteristics such as leaf/stem ratio for enhanced quality, with lesser emphasis on yield. In general, there appears to be a yield advantage by sowing later-maturing cultivars in autumn, and by sowing earlier. Later sown wheat and triticale had a better gross margin per hectare per day compared with the earlier sown crops. Likewise, an earlier harvest can also result in good margins per day where total duration from sowing to harvest is decreased. An earlier harvest also created opportunities for other crops to follow whole crop silage and further increase overall profitability of the crop system.

The profitability of cereal silage production was strongly driven by yield. However, some of the potential differences between crop expenses in commercial situation was not replicated in the trials as similar management was applied over the trials. This work has shown significant differences between species and for cultivars within species. The marginal differences ($ per kg/day from sowing to harvest) was closely related to the net $/ha margin and the net profit returned in c/kg DM.

Acknowledgements

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