Effects of crop management on silage harvest timing for a new awnless barley (cv Monty)

J.M. de Ruiter and S. Maley
The New Zealand Institute for Plant & Food Research Limited, Private Bag 4704, Christchurch 8140, New Zealand

Abstract

The demand for high quality feed for the dairy industry in the South Island has created a new opportunity for cereal silage producers. Cereal silage can potentially supply a large proportion of the winter requirement while complementing other winter feeds such as kale and fodder beet. A trial with a new awnless barley cultivar (*Hordeum vulgare* L. cv Monty) was established at Lincoln, Canterbury, New Zealand on an irrigated and a dryland block. Factorial combinations of fungicide (control vs. strobilurin + triazole, nitrogen (N) fertiliser rate (50, 100 and 200 kg/ha) were applied on both blocks. A plant growth regulator treatment (Moddus and control) was included in the irrigated trial. Plots were arranged in a randomised complete block design with four replications, and measurements made of crop % dry matter and crop yield at predefined whole crop silage development stages representing early, mid and late harvest. The objective of the study was to manage leaf area duration to influence the dynamics of drying rate driven by thermal time and to define best strategies for widening the harvest window. Within both the dryland and irrigated sites, N fertiliser had an effect on crop dry-down influencing the DM% at awn tip appearance but not the rate of crop dry-down. Other agronomic treatments (fungicide, growth regulator) had no effect on temporal patterns of crop dry-down. Nitrogen fertiliser was the only management option tested that growers could effectively use to manipulate the harvest timing for silage.

Additional keywords: dry matter content, silage quality, leaf area, whole crop silage

Introduction

In the South Island of New Zealand there is an increasing demand for high quality feed for wintering dairy cows and for supplementation while lactating. Numbers of dairy cows have continued to increase and in Canterbury alone rose 19% between 2011 and 2012 (Agricultural Production Statistics, 2012). Cereals provide many options for supplementary feeding, including green-feed, straw, grain and conserved product (FAR 2002a, 2006) for use at any time of the year to alleviate feed shortages (Stevens *et al.,* 2004). The value of cereal silage to the dairy farmer is in the quality of feed if crops are grown with sufficient inputs and conserved well (de Ruiter, 2001; de Ruiter *et al.,* 2002). Crops are traded on a dry matter basis so both dairy users and crop producers have an interest in rate of drying and its relationship with harvest timing and it effect on quality.

Timely application of irrigation, nitrogen (N) fertiliser, fungicides and plant growth regulators can be used to improve the consistency of whole crop silage quality

(FAR 2002b, 2002c, 2007). These management options increase leaf longevity, reduce incidence of leaf necrosis through leaf rust, scald net blotch and powdery mildew, and altering leaf to stem ratio. These factors influence the rate and duration of whole crop dry-down. High quality is achieved by ensuring that the crop is harvested when there is sufficient moisture for ensiling and a high level of grain fill (FAR 2002d, 2003). Windows for 'safe' harvesting for silage need to be extended to reduce the risk of poor silage quality. Barley (*Hordeum vulgare* L.) silage crops provide a challenge for optimising harvest timing for best yield and quality (FAR, 2003), as the opportune time for making silage is short.

The objective of this experiment was to determine if yield and the rate of progress to silage maturity for a new awnless barley cultivar 'Monty' (AgriCom, New Zealand), could be adjusted by crop management, and therefore reduce the risks associated with managing harvest timing.

Materials and Methods

The trial location was at the New Zealand Institute for Plant & Food Research Limited, Boundary Road (43° 49' 48" S, 171° 43' 12" E), Canterbury, in New Zealand on a Templeton silt loam (Typic Ustochrept, USDA soil taxonomy) with 175 mm readily available water, (S Map, Lilburne *et al.*, 2012). The cropping history for the trial area was maize, cereals, spring barley in 2008, 2009, and 2010; with 'Grasslands Nui' ryegrass in 2011 through to the end of August 2012. Old pasture sprayed with 3 l/ha of Roundup® and 20 g/ha of Granstar® in 200 l/ha of water on 1 August 2012. A pre-season soil test was done on 24 August for mineral (Q test) and available mineral N (AMN). The seedbed was ploughed, Cambridge rolled, then power harrowed and rolled twice more.

The trial was sown on 3 September with a Taege direct-drill at 160 kg/ha with the barley cultivar ('Monty'). Cropzeal 16N (150 kg/ha; 23.4 kg/ha of N, 12 kg/ha of P, 15 kg/ha of K and 14.4 kg/ha of S) fertiliser was applied at sowing. The crop emerged on 17 September with a mean population (determined on 20 quadrats of 0.3 m^2 on 20 September) of 301 plant/m^2 (sd = 41.7) for the dryland block, and 306 plant/m^2 (sd = 38.4) for the irrigated block.

The whole trial area was sprayed for weeds with Cougar® 1 l/ha and Glean® at 15 g/ha mixed with Karate® at 40 ml/ha for aphids, all in 200 l/ha of water on 5 October Additional herbicide (150 g/ha of Hussar + 1 l/ha of Partner®) was applied with 200 l/ha of water on 11 October. An early fungicide (Opus® at 300 ml/ha and Amistar® at 300 ml/ha) incorporating 250 g/ha Pirimor for aphid control, was applied in 200 l/ha of water on 2 November.

Treatments and experimental design

The trial area consisted of dryland and irrigated blocks that were run as separate randomised complete block (4 replicates) experiments. Nitrogen rate (50, 100 and 200 kg N/ha) as main plots and fungicide (control and strobilurin + triazole) treatments were the same within dryland and irrigated environments. Fungicide applications consisted of 0.4 l/ha (Amistar, active ingredient 500 g/kg azoxystrobin) + 0.25 l/ha Opus® (active ingredient 125 g/l epoxiconazole) in 150 l water/ha applied at GS37 (flag leaf visible) on 28 November. An additional treatment comprising control (nil) and Moddus® (active ingredient trinexapac-ethyl) at 0.4 l/ha in 200 l/ha of water applied to the irrigated block on 7

November when plants were at first node (GS31), (Tottman *et al*., 1979).

The fertiliser N treatments were selected to replicate typical grower N management beginning at GS31 with a low rate. Medium and high rates were designed to prolong green leaf duration. The N (as urea) treatments were split into early N (first node detectable, GS30 on 31 October) that was designed to maintain tiller populations and the later application (GS32, second node) to support leaf area. Treatment 1 received 50 kg N/ha and both treatments 2 and 3 received 100 kg N/ha followed by 10 ml of irrigation. The second application of 100 kg N/ha was applied on 13 November to treatment 3 only. Ten ml of irrigation water was again applied to soil incorporate the fertiliser.

The trial was sown on 3 September with a Taege drill fitted with an Oyjord cone distributer. Plots measured 10 m x 1.95 m plots with 15 cm row spacing, and 30 cm spacing between plots. Two buffer plots were sown on the ends of the trial.

Soil water was monitored by neutron probe in four dryland and four irrigated plots, split between control and high N treatments. Access tubes were installed on 23 September to a soil depth of 1.5 m. Soil moisture was measured at 2-week intervals beginning on 2 October. The irrigated block received 135 mm of water spread over five applications starting on 23 November, finishing on 27 December with a maximum application rate of 30 mm per event.

Measurements

Two treatments (4 replicates) were identified in each of irrigated and dryland blocks for increased frequency of sampling for % dry matter content (%DM). These were selected on the basis of the likely widest range in crop development within the respective blocks. Plant dry matter content was determined on 400 g FW samples cut to stubble height of 2.5 cm and dried at 90°C for 24 hours in a forced draught oven. Full trial harvests for yield and %DM were scheduled when the dry matter contents reached 30 (H2), 38 (H3) and 46% (H4), respectively. An early harvest (H1) was taken for %DM (but no yield measurement) when the crop was at ear emergence stage (GS49). All plots were harvested on the same day (irrespective of possible treatment effects on %DM), except the penultimate and final harvests of the irrigated trial. These spanned 3 and 4 days, respectively, to accommodate the range in crop maturation.

Quadrat samples for yield were 0.5 m^2 and plot yields were corrected for %DM by the same method previously described. Additional subsamples comprising 20 tillers were taken for partitioning into leaf and stem, and leaf area index (LAI) calculated from measurement of leaf area (LI-COR model LI-3100, Lincoln, Nebraska) and adjusted for equivalent plot DW. Specific leaf area (SLA; cm^2/g) was determined on a leaf dry weight basis.

Digestibility of whole crop cereal samples were determined by NIRS at FeedTech (AgResearch, Palmerston North) on freeze dried samples ground to pass a 1 mm screen. Meteorological data were recorded on-site and summaries for rainfall, temperature and radiation covering the growing period are given in Figure 1.

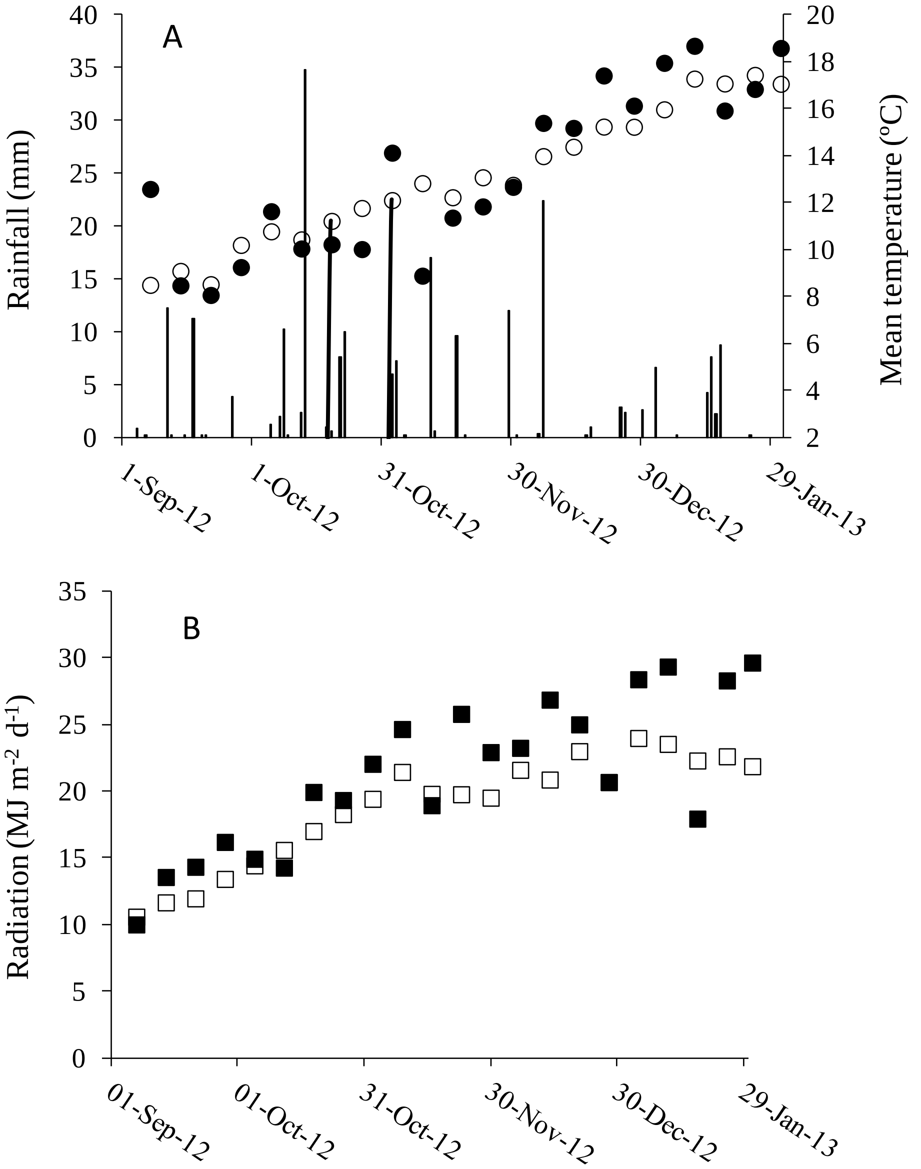

Figure 1: Daily rainfall (bars) and 7-day means for temperature (A) and radiation (B) at Lincoln (2012-13). Closed symbols are observed 7-day means and open symbols are long-term 7-day means.

Data analysis

Data were analysed using ANOVA, GenStat v.14 (VSN International, Hemel Hampstead, United Kingdom). Where multiple harvests were taken, independent ANOVA for successive time steps were run to test main effects. Response variables were plot yield, whole crop %DM, yield components and crop quality characteristics. General linear regression was used to test treatment effects explaining dry matter change in response to thermal time for independent irrigated and dryland sites. An estimate of the variability associated with predicted means is given by the 5% Least Significant Difference (LSD). Checks were made for distribution of residuals and for homogeneity of variances.

Dry matter change during grain maturation was fitted according to the linear model:

$$\%DM = \alpha_j + \beta_j \sum_{i=1}^{n} X_i + e_j \qquad \text{(Equation 1)}$$

where X_i = mean daily temperature (base 0°C) for the period, i = day of ear emergence (GS49), n = final %DM (<50% DM), j = plot number (full analysis) or treatment mean (combined analysis), and fitted parameters α and β.

Data were fitted on a plot by plot basis to estimate starting values for crop %DM at ear emergence (α), and rate of crop drying (β). Parameters derived for the slope and intercept terms were used as input data for testing treatment effects in an extended analysis. Treatment effects were also verified for respective irrigated and dryland blocks using a general linear regression and a pooled residual used for testing factor effects and for estimating parameters describing crop dry-down. Thermal time was calculated as the difference between the daily mean temperature and an assumed base temperature of 0°C (McMaster and Wilhelm, 1997).

The use of ANOVA to test for management effects was not always appropriate as not all plots were sampled on the same day. Therefore, a regression approach was used to test for treatment effects. Individual plots were sampled as close as practical to predefined 32, 38 and 46% DM stages to enable valid comparisons for quality in subsequent analyses that relate to dry matter development stage.

Results and Discussion

Soil properties

The soil contained adequate minerals for unrestricted growth (Table 1). General fertiliser (including N) was applied at sowing to minimise soil fertility effects. The fertiliser N treatments were designed to replicate typical grower N management beginning at first node development (GS31) with a low rate, and medium and high rates designed to prolong green leaf duration.

Soil water

Differences in soil water content between the irrigated and dryland blocks only became apparent in mid-November when the crops were approaching ear emergence (Figure 2). The maximum soil deficit for the dryland treatment was 130 mm (24 December) compared with a maximum deficit of 87 mm for the irrigated block (22 January). The difference in plant-available water between the irrigated and dryland treatments was 106.5 mm on 8 January (Figure 2) (0.08-0.35 v/v soil water content). While it appeared there was significant available water in the lower soil profile, this was probably not all available to the plants as the crops were actively senescing and root function was in decline.

Table 1: Soil minerals, mineral N and anaerobically mineralisable nitrogen (AMN) from a pre-season soil tests at Lincoln (sampled 24 August 2012).

Depth (cm)	pH	P mg/l	K QT	Ca µg/ml	Mg QT	Na QT	SO_4 QT
0-15	6.3	16	7	10	13	7	5

	Mineral N				
	Ammonium (ppm)	Nitrate (ppm)	Total (ppm)	Total[a] (kg N/ha)	AMN (kg N/ha)
0-15	1.6	12.0	13.6	20.4	90
15-30	1.1	7.0	8.1	12.2	38
30-60	0.5	7.3	7.8	11.7	79
60-100	0.6	3.0	3.6	5.4	42

[a] Assuming bulk density of 1.0.

Crop development

Differences in crop development induced by treatments were small. For example, there was only 5 days between the timing of ear emergence in the dryland (29 November) and irrigated (3 December) and blocks. There was no apparent difference in crop development due to fungicide or plant growth regulator treatments, but there was a delay in silage maturity (46% DM) of up to 5 days for high N compared with the no N plots.

Crop yield and leaf area development

Crop yield was determined at three stages of growth (nominally at mean %DM contents of 30, 38 and 46% DM). The crops developed rapidly because of the unusually warm dry conditions and higher than average solar radiation in mid-summer (Figure 1), and as a result some harvests were taken after the crops had reached their intended %DM target. Harvests were taken when crops attained respective mean dry matter contents of 33.6, 39.0 and 54.4% in the dryland block and at 26.1, 36.3 and 52.1% in the irrigated block.

At the optimum %DM for silage (38% DM), treatment effects were dominated by responses to N fertiliser application. In the irrigated block, the total harvestable silage ranged from 12.9 to 15.3 t/ha for the low (50 kg/ha) to high (200 kg N/ha) N input range (Table 2). A small contribution to the yield differences could be attributed to the maintenance of higher leaf area in high N plots. There was a significant ($P=0.016$) effect of N rate on green leaf area at the ideal harvest DM% (H3) (range 0.24–0.86 cm^2/cm^2), and there was also a significant ($P=0.014$) leaf area response to fungicide (Stobilurin + Triazole) application. While there was no significant effect of fungicide on yield, there was the possibility that crop quality may be improved by extending the duration of green leaf area. The proportion of leaf to total biomass was influenced by N rate ($P=0.014$) and by fungicide application ($P=0.017$). In addition, there was a significant ($P=0.029$) effect of fungicide on specific leaf area (142.7-159.1 g/cm^2 for mean of control and plus fungicide treatments). Further, it is possible that secondary effects involving green leaf area and leaf longevity may influence the rate of crop maturation and crop dry-down with subsequent effects on crop quality.

In the dryland block, the responses to treatments were similar to the irrigated block (Table 3). Nitrogen fertiliser was a strong driver of yield (P<0.001). These effects were mediated through N fertiliser effects on specific leaf area (P=0.056) and on leaf area index (P<0.001) as well as a significant (P=0.050) effect of fungicide treatment on LAI (range 0.775–1.012). For both irrigated and dryland trials, the PGR effects and all interactions involving fertiliser N and fungicide were not significant (P>0.05).

Digestibility

Nitrogen fertiliser effects on digestibility were not consistent at all stages of development, however there were significant effects in two of three harvests in both irrigated and dryland situations. Fungicide and PGR treatments had little effect on the quality (digestibility) of herbage.

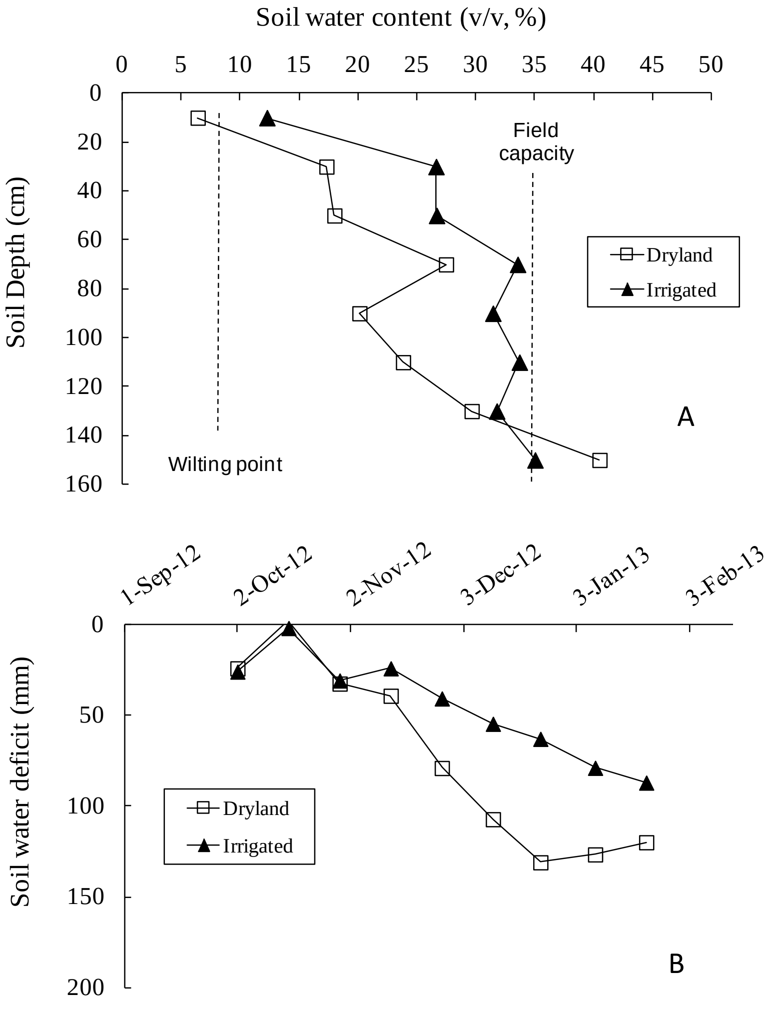

Figure 2: Soil moisture measurements made on 3 January (A) and temporal profile soil water content (B) for dryland and irrigated treatments at Lincoln (2012-13).

Table 2: Fertiliser N, fungicide and PGR effects on yield components and digestibility for respective harvests at the irrigated Lincoln site.

	Treatment			Yield component					
Harvest	Fertiliser N rate	Fungicide[a]	Plot yield (t/ha)	%DM	SLA[c] (cm^2/g)	LAI	Leaf/Total[d]	Ear/Total[e]	Digestibility (%)
2 (20 Dec)	50 kg N/ha	Control	9.9	28.8	161.5	1.24	0.08	0.44	54.3
		+	10.0	28.4	--	--	--	--	54.5
	100 kg N/ha	Control	10.8	25.9	--	--	--	--	56.2
		+	10.6	25.5	--	--	--	--	55.8
	200 kg N/ha	Control	11.4	25.0	--	--	--	--	58.3
		+	11.7	22.8	195.1	3.35	0.15	0.35	57.9
	$LSD_{0.05}$ (Pr>F)	N Fertiliser	0.882 (0.001)	1.001 (0.001)	--	--	--	--	1.037 (<0.001)
	$LSD_{0.05}$ (Pr>F)	Fungicide	NS	0.817 (0.020)	--	--	--	--	NS
	$LSD_{0.05}$ (Pr>F)	PGR	NS	NS	--	--	--	--	0.847 (<0.001)
3 (2-9 Jan)	50 kg N/ha	Control	12.9	37.2	143.8	0.29	0.013	0.59	NS
		+	12.8	37.5	170.3	0.26	0.012	0.60	NS
	100 kg N/ha	Control	14.3	37.2	121.9	0.24	0.012	0.58	NS
		+	15.1	36.8	165.0	0.71	0.028	0.58	NS
	200 kg N/ha	Control	15.1	35.4	142.9	0.48	0.020	0.58	NS
		+	15.5	33.8	161.6	0.86	0.032	0.58	NS
	$LSD_{0.05}$ (Pr>F)	N Fertiliser	0.750 (0.001)	--[b]	NS	0.366 (0.016)	0.0129 (0.014)	0.0116 (0.022)	NS
	$LSD_{0.05}$ (Pr>F)	Fungicide	NS	--[b]	26.15 (0.029)	0.299 (0.014)	0.0105 (0.017)	NS	NS
	$LSD_{0.05}$ (Pr>F)	PGR	NS	--[b]	--	--	--	--	NS
4 (10-14 Jan)	50 kg N/ha	Control	13.9	51.7	--	--	--	--	60.1
		+	13.5	50.7	--	--	--	--	60.3
	100 kg N/ha	Control	15.1	50.6	--	--	--	--	61.4
		+	15.9	48.9	--	--	--	--	61.5
	200 kg N/ha	Control	15.9	55.7	--	--	--	--	58.9
		+	16.8	55.0	--	--	--	--	59.2
	$LSD_{0.05}$ (Pr>F)	N Fertiliser	0.864 (0.001)	--[b]	--	--	--	--	1.094 (<0.001)
	$LSD_{0.05}$ (Pr>F)	Fungicide	NS	--[b]	--	--	--	--	NS
	$LSD_{0.05}$ (Pr>F)	PGR	NS	--	--	--	--	--	NS

[a] Fungicide = control (nil) or treated with Strobilurin + Triazole. [b] Comparisons were not appropriate as harvest timing was not consistent across treatments. NS, treatment effects non-significant. [c] Specific leaf area. [d] Leaf component as a fraction of total yield. [e] Ear component as a fraction of total yield.

Table 3: Fertiliser N and fungicide effects on yield components and digestibility for respective harvests for the dryland site at Lincoln.

Harvest	Treatment		Plot yield (t/ha)	Yield component					Digestibility (%)
	Fertiliser N rate	Fungicide[a]		%DM	SLA[c] (cm^2/g)	LAI	Leaf/Total	Ear/Total	
2 (20 Dec)	50 kg N/ha	Control	10.6	34.3	109.7	0.85	0.069	0.48	54.5
		+	9.9	33.8	--	--	--	--	56.0
	100 kg N/ha	Control	10.9	35.4	--	--	--	--	55.1
		+	10.6	35.4	--	--	--	--	55.5
	200 kg N/ha	Control	10.4	31.7	--	--	--	--	57.6
		+	10.5	30.8	134.3	1.55	0.111	0.47	58.3
	LSD$_{0.05}$ (Pr >F)	N Fertiliser	NS	2.69 (0.014)	--	--	--	--	1.29 (0.014)
	LSD$_{0.05}$ (Pr >F)	Fungicide	NS	NS	--	--	--	--	NS
3 (28 Dec)	50 kg N/ha	Control	11.8	40.6	128.4	0.59	0.044	0.59	57.4
		+	11.2	39.9	128.4	0.42	0.029	0.61	56.6
	100 kg N/ha	Control	12.9	39.9	131.1	0.54	0.033	0.60	58.2
		+	13.2	39.2	157.0	1.15	0.054	0.58	57.8
	200 kg N/ha	Control	13.6	37.4	155.4	1.23	0.058	0.59	58.0
		+	13.7	37.0	158.0	1.46	0.068	0.59	59.1
	LSD$_{0.05}$(Pr >F)	N Fertiliser	0.76 (0.001)	0.98 (0.001)	22.8 (0.056)	0.290 (0.001)	0.0196 (0.032)	NS	1.26 (0.008)
	LSD$_{0.05}$ (Pr >F)	Fungicide	NS	NS	NS	0.237 (0.05)	NS	NS	NS
4 (7 Jan)	50 kg N ha^{-1}	Control	12.9	56.7	111.9	0.01	0.001	0.67	59.0
		+	11.3	57.2	--	--	--	0.66	58.9
	100 kg N/ha	Control	13.9	54.7	115.5	0.08	0.005	0.65	59.1
		+	13.4	52.8	144.0	0.04	0.002	0.65	58.8
	200 kg N/ha	Control	14.5	51.4	112.7	0.05	0.003	0.64	58.7
		+	13.4	53.7	60.0	0.01	0.001	0.66	58.9
	LSD$_{0.05}$ (Pr >F)	N Fertiliser	1.29 (0.017)	-- [b]	NS	0.040 (0.037)	0.0016 (0.018)	NS	NS
	LSD$_{0.05}$ (Pr >F)	Fungicide	1.05 (0.041)	-- [b]	NS	0.033 (0.015)	0.0013 (0.009)	NS	NS

[a] Fungicide = control (nil) or treated with Strobilurin + Triazole.

[b] Comparisons were not appropriate as harvest timing was not consistent across treatments.

[c] Specific leaf area.

NS = treatment effects non-significant.

Treatment effects on crop moisture content

In the irrigated block (Table 2), whole crop %DM at the second harvest (20 December) showed a significant difference ($P<0.001$) due to N rate, and there was also a significant fungicide effect ($P<0.02$) on %DM. Mean %DM at this time was 26.1% with a range of 22.8-28.8% for the range of N and fungicide treatment combinations. In the dryland block, the fertiliser N effect was significant ($P<0.007$), but there was no response to fungicide. In this case, there was a 4.1% DM difference in moisture content with a mean of 28.6% DM across all plots. At harvest date 4, (7 January), the %DM had risen rapidly to a mean of 39% DM for a 3% difference in moisture content due to N treatment.

Pattern of crop dry-down

Crop dry-down, as shown in selected indicator plot treatments (Figure 3A), was best fitted with a quadratic response to calendar days after ear emergence. Crops dried down at an increasing rate and passed through the ideal silage harvest window of 35-45% DM over 7 days.

Indicator plots showed a linear response for crop dry-down plotted against accumulated thermal time after ear emergence with a reliable prediction range (20-45% DM) (Figure 3B). At DM >50% there was a transition into a higher rate. The initial dry-down phase was useful for predicting crop maturation with termination at the upper end for ideal silage making (40-50% DM). There was no difference in rate of dry-down for the selected treatments, and any differences due to the treatments were explained by the starting %DM.

A full analysis at the plot level tested whether treatments were effective in altering rate of dry-down or influenced the initial DM% (Tables 3 and 4). The first stage of crop dry-down showed a consistent linear fit across all treatments with only a marginally detectable lower rate for the irrigated high N treatment. There was a small yet statistically significant ($P=0.05$) difference among between N rates, and no difference ($P>0.05$) in dry-down (slope parameter β) under differing fungicide application or growth regulator treatment (Table 4). Dry-down rates within the crop cultivar (‘Monty’) were consisent irrespective of agronomic treatment (Figure 3B). Dry matter content of crops at ear emergence (intercept parameter, α) were different for the various N rates. The net effect was a vertical shift in the fitted lines that was explained by N rate alone. Differences in duration from ear emergence to silage maturity (45% DM) were driven by starting DM content in the respective N treatments.

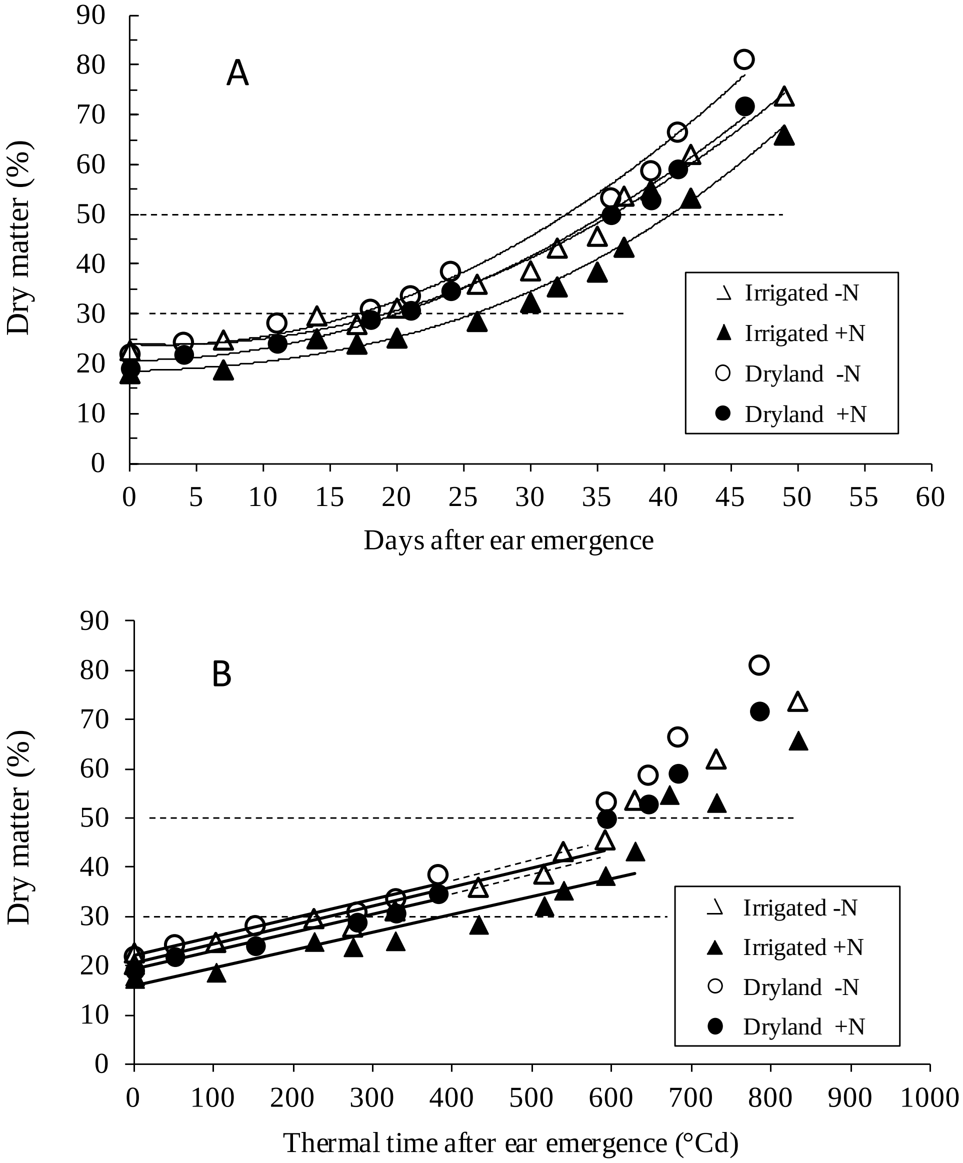

Figure 3: Progress of % dry matter change during grain development in response to calendar days (A) and accumulated thermal time (B). Data were fitted with a quadratic function (A), and to a linear model (B) for dry matter values below an observed threshold of 50% DM. Values between the limits 30-50% DM represent the best range for making silage.

Table 4: Fertiliser N, fungicide and growth regulator effects on parameters describing crop dry-down for irrigated and dryland crops at Lincoln. Regression analysis was done on individual plots for the dry-down period up to 50% DM only.

Site	Treatment	Parameters and standard errors				
	Fertiliser N	Mean Intercept α)	se (α)	Mean Slope (β)	se (β)	Mean r^2
Irrigated	50 kg N/ha	20.9	1.49	0.0339	0.0062	0.935
	100 kg N/ha	17.6	1.72	0.0362	0.0057	0.937
	200 kg N/ha	15.0	1.29	0.0385	0.0056	0.896
LSD$_{0.05}$ (Pr >F)	N Fertiliser	0.943 (0.001)		0.00139 (0.010)		
	Fungicide[a]	NS		NS		
	PGR[b]	NS		NS		
	Interactions	NS		NS		
Dryland	50 kg N/ha	21.6	1.12	0.0404	0.0017	0.960
	100 kg N/ha	19.8	1.58	0.0447	0.0049	0.956
	200 kg N/ha	19.3	1.60	0.0398	0.0035	0.937
LSD$_{0.05}$ (Pr >F)	N Fertiliser	0.903 (0.001)		0.00320 (1.333)		
	Fungicide[a]	NS		NS		
	Nit. x fungicide	1.277 (0.040)		NS		

[a] Fungicide = control (nil) or treated with Strobilurin+Triazole at GS39 in both irrigated and dryland trials.

[b] PGR = plant growth regulator, Moddus (dryland) applied at GS31 or control (nil on irrigated).

NS = treatment effects non-significant.

A general linear regression using stepwise fitting of N fertiliser, fungicide, and growth regulator factors showed that the only significant effects were due to N alone (P<0.001) for both the irrigated and dryland experiments (Table 5). Nitrogen treatment did, however, influence the starting values for %DM at ear emergence and thereafter the progress of crop dry-down was consistent across all N treatments. While a plot by plot analysis did show a significant drying rate effect due to N fertiliser for some treatment combinations, this result was not supported in the general linear regression. This confirmed the results of the analysis done on individual plots. However, there was some indication of a non random distribution of residuals, with intermediate DM% observations having less variation than higher values. This could be explained by irregular DM% measurements when crops were not fully dry at the time of sampling. Parameter estimates for drying rate were higher in the dryland block than in the irrigated block, but the differences between these were not testable in this study.

Table 5: Parameter values and errors for general linear regressions relating DM% with thermal time after ear emergence for crops grown under dryland or irrigated conditions. Parameters are given for model with common slope (β) and different intercepts (α) as given in equation 1.

		Parameters and standard errors of estimates			
Site	N treatment[a]	Intercept (α)	se (α)	Slope (β)	se (β)
Irrigated[b]	N1 (50 kg N/ha)	20.21	0.379	0.0370	0.0008
	N2 (100 kg N/ha)	17.42	0.409		
	N3 (200 kg N/ha)	15.45	0.386		
Dryland[c]	N1 (50 kg N/ha)	21.21	0.424	0.0418	0.0012
	N2 (100 kg N/ha)	20.70	0.496		
	N3 (200 kg N/ha)	18.63	0.431		

[a] Stepwise variance due to N treatment within site was significant at $P<0.001$.

[b] Effect of fungicide was not significant ($P>0.05$).

[c] Effects of fungicide and PGR were not significant ($P>0.05$).

Conclusions

In both irrigated and dryland trials, N rate had the strongest effect on %DM and, therefore, the projected timing of harvest. There was an effect of fungicide on %DM in the irrigated trial but only in the early harvest window (26.1% DM at 20 December). For the dryland block, full harvests were completed on 20 and 28 December when mean crops were at 28.6 and 39.0% DM, respectively. On both occasions N effects were significant but fungicide was not.

The curvilinear pattern of crop dry-down in response to calendar days meant this was not a useful method for predicting harvest timing. The patterns were likely to be different depending on the the agronomic treatment imposed. The rate of crop dry-down occurred at an increasing rate with time and therefore quickly passed the point for ideal silage making. This left little opportunity for managing the silage harvest using agronomic treatments designed to extend or delay the harvest window.

On the other hand, the pattern of dry-down was related to thermal time after ear emergence (GS49) and the responses were linear only if data for crop %DM were restricted to samples less than 50% DM. Beyond that stage, dry-down was still linear but occurred at a faster rate. This step change in crop dry-down could be related to the particular season (hot and dry during late grain filling) or a characteristic of the cultivar, being an awnless type with reduced glume protection for developing kernels.

None of the analyses showed consistent effects of fungicide or growth regulator on parameters for crop dry-down (in relation to thermal time). A differential drying rate for N fertiliser rates in a plot by plot analysis was not supported in the general linear regression analysis, but starting values for %DM at ear emergence responsed to N fertiliser rate. A universal dry-down rate can therefore be derived for cultivar ‘Monty’ that covers all treatents tested in this experiment and adjustments to harvest timing induced by N management can be made for variable DM% at ear emergence.

While N fertiliser was effective in delaying crop maturation, the extent of the response was small with a maximum of 5 days delay. There was little opportunity to use crop management to lengthen the harvest window other than by applying fertiliser to maintain a green crop for longer.

Acknowledgements

This study was funded by MPI Sustainable Farming Fund and Foundation for Arable Research. Assistance during trial work was provided by Alex Noble and Hannah Priergaard-Petersen.

References

Agricultural Production Statistics 2012 http://www.stats.govt.nz/browse_for_stats/industry_sectors/agriculture-horticulture-forestry/AgriculturalProduction_final_HOTPJun12final.aspx, accessed 20 June 2013.

de Ruiter, J.M. 2001. Growth potential of spring forage cereals for silage. *Agronomy New Zealand* 31: 99-107.

de Ruiter, J.M., Hanson, R., Hay, A.S., Armstrong, K.W. and Harrison-Kirk, R.D. 2002. Whole-crop cereals for grazing and silage: balancing quality and quantity. *Proceedings of the New Zealand Grassland Association* 64: 181-189.

FAR, 2002a. The whole-crop cereal silage option. FAR Arable Extra No. 113 2 pp.

FAR, 2002b. Nitrogen use for spring barley crops. FAR Arable Extra No. 117 2 pp.

FAR, 2002c. PGRs on spring barley. FAR Arable Extra No. 122 2 pp.

FAR, 2002d. Cutting times and quality of whole crop cereal silage FAR Arable Extra No. 124 2 pp.

FAR, 2003. Changes in whole crop cereal silage at varied cutting times. FAR Arable Extra No. 140 2 pp.

FAR, 2006. Cereal supplements and their role in dairy enterprise. FAR Arable Extra No. 170 2 pp.

FAR, 2007. Spring sown barley disease control - susceptible variety FAR Arable Extra No. 188 2 pp.

Lilburne, L.R., Hewitt, A.E. and Webb, T.W. 2012. Soil and informatics science combine to develop S-map: A new generation soil information system for New Zealand. *Geoderma*. 170: 232-238.

McMaster, G.S. and Wilhelm, W.W. 1997. Growing degree-days: one equation, two interpretations. *Agricultural and Forestry Meteorology* 87: 291-300.

Stevens, D.R., Platfoot, G.J., Hyslop, M.G., Knight, T.L., Corson, I.D. and Littlejohn, R.J. 2004. Dairy cow production when supplemented with whole-crop cereal silages in spring and autumn. *Proceedings of the New Zealand Grassland Association* 66: 75-82.

Tottman, D.R., Makepeace, R.J. and Broad, H. 1979. An explanation of the decimal code for the growth stages of cereals, with illustrations. *Annals of Applied Biology* 93: 221-234.