Dry matter accumulation of oats sown at five different sowing dates

M.Y. Martini[1], B.A. McKenzie[1], D.J. Moot[1], G.D. Hill[1] and J.M. de Ruiter[2]
[1]Faculty of Agriculture and Life Sciences, Lincoln University, PO Box 84, Lincoln 7647, Christchurch, New Zealand
[2] The New Zealand Institute for Plant & Food Research Limited, Canterbury Agriculture and Science Centre, Gerald St, Lincoln 7608, New Zealand

Abstract

In crop rotations the harvest date of the first crop affects the sowing date of the succeeding crop which then influences the potential annual yield of the rotation. This study measured the dry matter accumulation and growth rate of oats, cv Milton, sown on five different dates 4 March (S_1), 28 March (S_2), 21 April (S_3), 12 May (S_4) and 3 June (S_5) in 2008. Each sowing was sequentially harvested until October. More than 15 t DM ha^{-1} was obtained from oats sown in March but the yield declined to 7.7 t DM ha^{-1} in the June sowing. Using a base soil temperature of 0 °C Milton accumulated yield at between 8 and 13 kg DM $°Cd^{-1}$. The earlier autumn sowings accumulated more heat units and therefore had higher dry matter production. Winter growth of S_4 and S_5 was < 19 kg DM ha^{-1} d^{-1}. Low growth rates in these treatments occurred because they failed to reach a critical leaf area index before cool temperatures restricted canopy development. However, these later sown crops responded rapidly to warm spring temperatures. The final yield from the October harvest reflects the yield potential prior to sowing a maize or kale crop for summer.

Additional keywords: *Avena sativa*, harvest date, thermal time, forage

Introduction

In New Zealand oats (*Avena sativa* L.) are used as supplementary forage in pasture and crop rotations (Moot *et al*., 2007). Oats have better growth than other crops in declining autumn temperatures and also have good seedling vigour (Forsberg and Reeves, 1995). They are therefore more suited to late sowing than most other annual forage crops. Oat crops are often sown after summer forages such as rape (*Brassica napus* L.) and maize (*Zea mays* L.) and are sown into cultivated soils or are direct drilled into seedbeds that would be unsuitable for other crops, such as annual ryegrass (*Lolium multiflorum* Lam.).

Planting an oat crop is often the best option if sowing has been delayed or seedbed preparation is not ideal. However, the onset of cool autumn temperatures can be expected to decrease potential growth rates.

Thus, determining how late in autumn a crop can be successfully sown is an important management decision for growers. If crops are sown too late they may fail to reach canopy closure before cool autumn and winter temperatures restrict leaf appearance and consequently crop growth is compromised. Subsequently, the time of final crop harvest may depend on whether the crop is to be grazed, ensiled or taken for seed. This paper reports on an experiment that studied crop growth from each sowing date through to mid spring when the next crop in a rotation may need to be sown. In this study, to determine the effect of sowing and harvest date on crop yield, light interception was monitored and growth rates were related to temperature using thermal time (Mills *et al*., 2006).

Materials and Methods

Experimental site

The study was conducted at Block H14, Lincoln University, Canterbury, New Zealand. The soil was a Tempelton silt loam (Typic Ustochrept, USDA soil taxonomy). The experiment site had been in a barley trial the previous year. A Ministry of Agriculture and Fisheries (MAF) soil quick test was done and soil test results are reported in Table 1. In this study, the oat (*Avena sativa* L.) cultivar 'Milton', was sown on five different dates (4 March (S_1), 28 March (S_2), 21 April (S_3), 12 May (S_4) and 3 June (S_5) of 2008) as part of an experiment that also included tick bean (V*icia faba* L.) and Italian ryegrass (*Lolium multiflorum*). This paper, only reports the results for oats.

Experimental design and management

The experiment was a split-plot design with four replicates. The five sowing dates were main plots and crop species were sub-plots. The oats were sown with an Oyjørd cone seeder at 240 plants m^{-2}. The target sowing depth was 20 mm. Experimental sub-plots were 14 x 2.1 m with 150 mm between rows. All five sowings received 500 kg N ha^{-1} in 10 split equal applications of 50 kg N ha^{-1} as urea during the growing season. The rate of 50 kg N ha^{-1} was based on standard farm practise. Irrigation was applied when the soil moisture was 20% below field capacity as measured by a plug-in Hydrosense probe about 27 cm deep in the soil. Monitoring was to avoid water stress during the growing season. Temperature probes (Hobo shuttle) were placed in the plots to measure soil and air temperature. For weed control, MCPA (375 g l^{-1} MCPA) was applied at 3 l ha^{-1} on 3 April 2008. Pirimor 50 insecticide (500 g kg^{-1} pirimicarb) was applied for aphid control at 250 g ha^{-1} on 8 April, 29 May and 28 August 2008.

Measurements

Dry matter accumulation and thermal time

Dry matter (DM) accumulation, was measured at approximately fortnightly intervals until October 2008. Sampling was done three weeks after the crop was sown using two 0.1 m^2 quadrats. Oats were cut to ground level from each of the three rows across the plot. Samples were weighed and oven-dried at 50-60 °C to constant weight. At final harvest a 0.5 m^2 quadrat was used. Daily mean soil temperatures from temperature sensors placed at 25 mm depth in the experimental plots were used for thermal time (Tt) calculations with a base temperature of 0 °C.

Radiation interception and leaf area index

Leaf area index (LAI) and the amount of radiation transmitted through the canopy were measured using a plant canopy analyser LAI-2000 (LI-COR Inc., Lincoln, Nebraska, USA). Measurements were made weekly in March, April and May, once every two weeks in June, July and August and weekly again in September and October.

Data analysis

Results were analysed using analysis of variance (Genstat 11) across all sowing dates. Mean separation was by Fisher's protected least significant difference method. Linear regressions were performed for DM and leaf area index against Julian days. Points for the regression were excluded from late winter or when DM yield started to increase in early spring (Figure 1) due to a loss of linearity in the data set. In contrast, all points up to maximum DM for all sowing dates were included in the regression against thermal time.

Table 1: Soil test results (0-15 cm) for Block H14 Horticulture Research Area, Lincoln University, Canterbury, New Zealand.

Year	pH	Olsen-soluble P (µg ml^{-1})	Ca MAF	Mg MAF	K MAF	Na MAF	Sulphate (µg g^{-1})	Anaerobic mineralisable N (kg ha^{-1})
2008	5.9	23	8	20	7	8	2	42

Results

Dry matter yield

The maximum DM accumulation for autumn sowings was higher than for winter sowings with 14,620 kg ha^{-1} and 15,390 kg ha^{-1} for crops sown in March. Yields declined successively to 12,840 kg ha^{-1} for the April sowing to 7,730 kg ha^{-1} for the June sowing (Figure 1). In this study, oat DM yield did not increase after the end of October and in some instances the yield declined with time. Respective March-sown oats had faster early growth rates with 71 and 47 kg DM ha^{-1} d^{-1} than sowings in April, May and June. In the latter sowings, winter growth rates never exceeded 17 kg DM ha^{-1} d^{-1}. However, growth rates recovered to approximately 148 kg DM ha^{-1} d^{-1} during the September to October spring period (Figure 1).

Accumulated thermal time

Oats accumulated DM at about 9 kg DM °Cd^{-1} for the season when sown in March and averaged 12 kg DM °Cd^{-1} for the three final sowings (Figure 2). For all sowings the results showed a strong linear relationship between accumulated DM and accumulated thermal time. The earlier autumn sowings accumulated more heat units which allowed higher maximum DM yields. Specifically, the duration of growth was 1773 °Cd for the 28 March sowing (S_2) and this was associated with the highest DM yield accumulation.

Radiation interception, leaf area index and accumulated thermal time

Figure 3 shows that critical LAI ($LAI_{(crit)}$) for Milton oats was about 2.6. Virtually all sowing dates achieved $LAI_{(crit)}$. However, the time when this occurred differed among sowing dates.

For the 4 March sowing this was achieved by 9 June compared with a month later in S_2 on 6 July which was sown three weeks later. Delaying sowing a further three weeks to 21 April meant canopy closure was not achieved until 26 August. In the last two sowings, canopy closure did not occur until the following spring on 14 and 17 October 2008 respectively, (Figure 4). Figure 5 shows that the leaf expansion rate that drives canopy expansion, as measured by leaf area index, was related to thermal time. Based on the regression equations the accumulated thermal time was about the same (approximately 1029 °Cd for the March sowing, approximately 999 °Cd for the April and May sowing and 967 °Cd for the last June sowing) across all sowing dates.

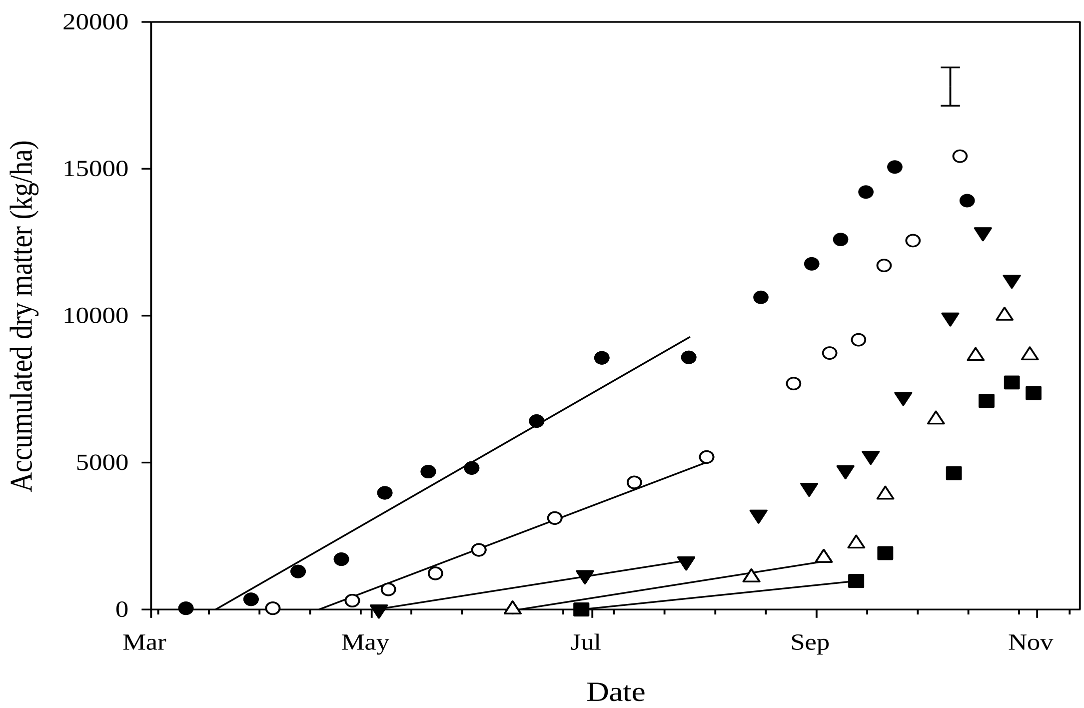

Figure 1: Dry matter accumulation from different sowing dates of Milton oats sown on 4 March (S_1) (●), 28 March (S_2) (■), 21 April (S_3) (▲), 12 May (S_4) (◆) and 3 June (S_5) (▼) 2008 at Lincoln University, Canterbury, New Zealand. Regressions which show winter growth rates are:
S_1 y = -5582 (± 699) + 70.8 (± 4.93)x (R^2 = 0.96),
S_2; y = -5023 (± 468) + 46.8 (± 2.10)x (R^2 = 0.97),
S_3, y = -2391 (± 162) + 19.4 (± 0.92)x (R^2 = 0.99),
S_4, y = -3158 (± 675) + 19.4 (± 3.14)x (R^2 = 0.95),
S_5, y = 12.7x - 2294 (*n*=2).
S.E.M presented means of maximum dry matter yield of five sowing dates.

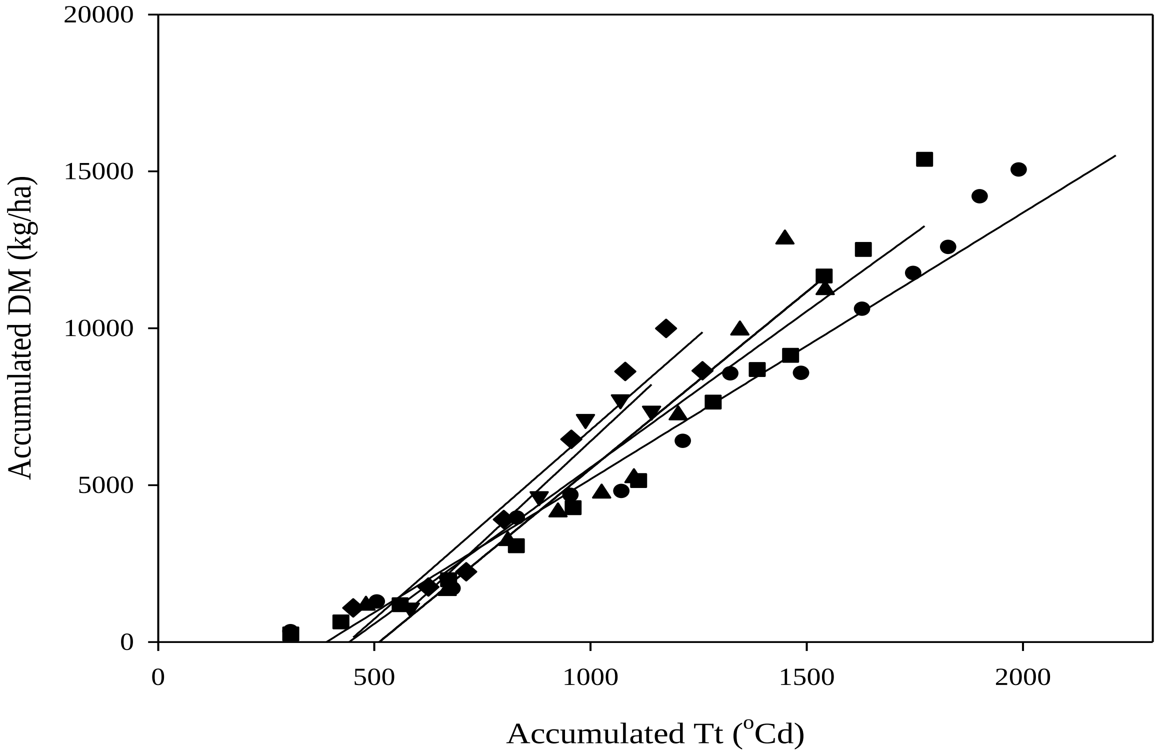

Figure 2: Dry matter accumulation against accumulated thermal time (Tt) with a base temperature 0 °C for ‘Milton’ oats sown on 4 March (S_1) (●), 28 March (S_2) (■), 21 April (S_3) (▲), 12 May (S_4) (◆) and 3 June (S_5) (▼) in 2008 at Lincoln University, Canterbury, New Zealand. Regressions are:
S_1, y = -3305 (± 599) + 8.49 (± 0.42)x, (R^2 = 0.97),
S_2, y = -440 (± 803) + 9.96 (± 0.69)x, (R^2 = 0.95),
S_3, y = -5774 (± 129) +11.3 (± 1.17)x, (R^2 = 0.91),
S_4, y= -5287 (± 124) +12.0 (± 1.34)x, (R^2 = 0.92),
S_5, y= -6424(± 121) +12.8 (± 1. 33)x, (R^2 = 0.95).

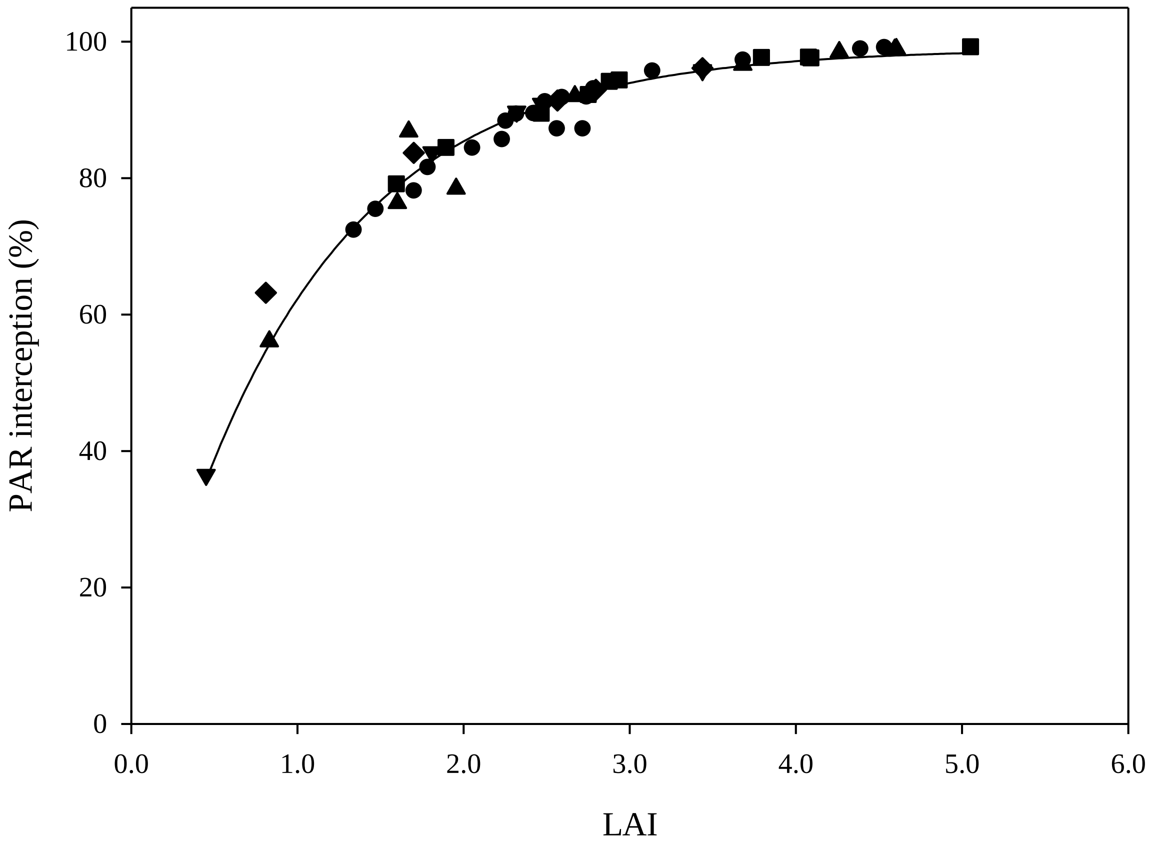

Figure 3: Intercepted photosynthetically active radiation (PAR) against leaf area index (LAI) for Milton oats sown on 4 March (S_1) (●), 28 March (S_2) (■), 21 April (S_3) (▲), 12 May (S_4) (◆) and 3 June (S_5) (▼) in 2008 at Lincoln University, Canterbury New Zealand. Form of the curve is:
y= 99.0 (± 0.68)x (1-0.(± 0.010)^x) (R^2 = 0.96).

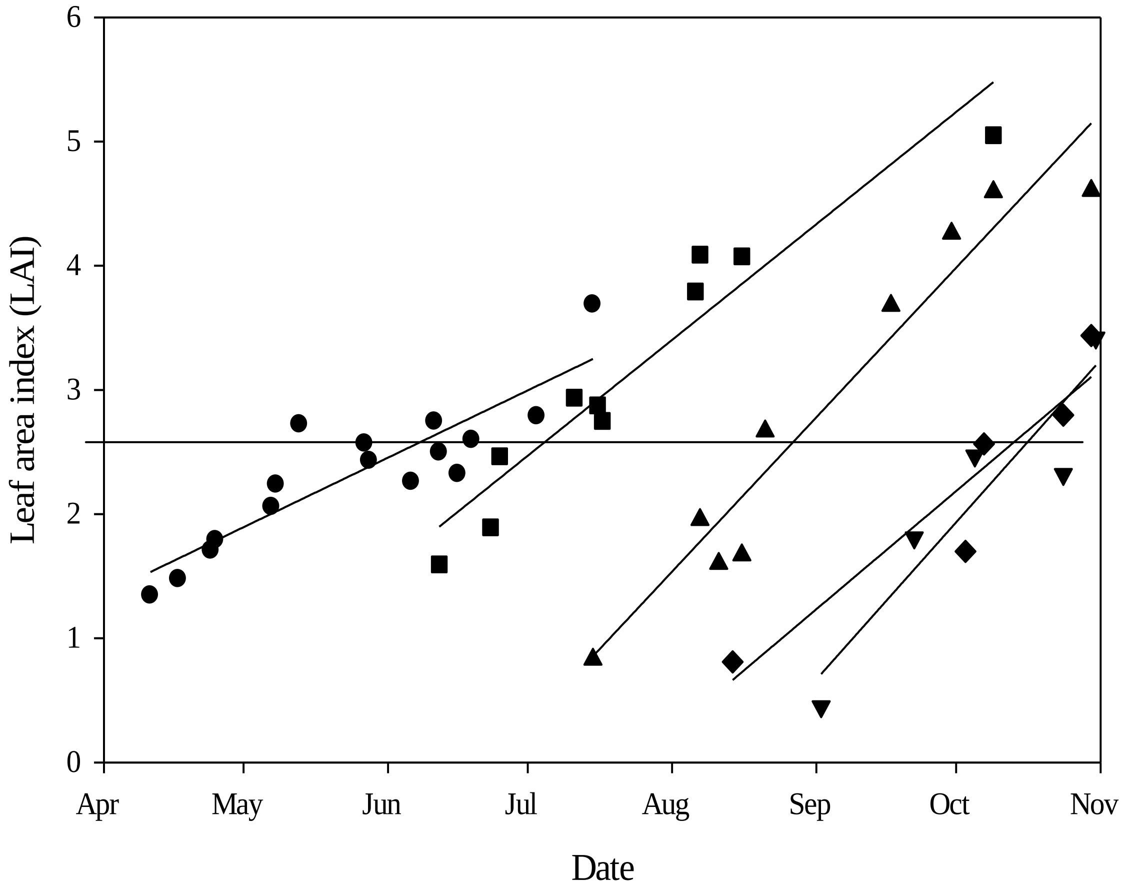

Figure 4: Leaf area index (LAI) of different sown dates for Milton oat crops sown on 4 March (S_1) (●), 28 March (S_2) (■), 21 April (S_3) (▲), 12 May (S_4) (◆) and 3 June (S_5) (▼) in 2008 at Lincoln University, Canterbury, New Zealand. Regressions are:

S_1, y = -0.3254 (± 0.3704) + 0.0182 (± 0.0025)x, (R^2 = 0.78),
S_2, y = -4.7840 (±0.6624) + 0.0392 (± 0.0033)x, (R^2 = 0.94),
S_3, y = -7.0485 (± 0.9657) + 0.0401 (± 0.0039)x, (R^2 = 0.93),
S_4, y = -6.5307 (± 1.8419) + 0.0317 (± 0.0066)x, (R^2 = 0.85),
S_5, y = -9.6560 (± 2.7340) + 0.0421 (± 0.098)x, (R^2 = 0.81).

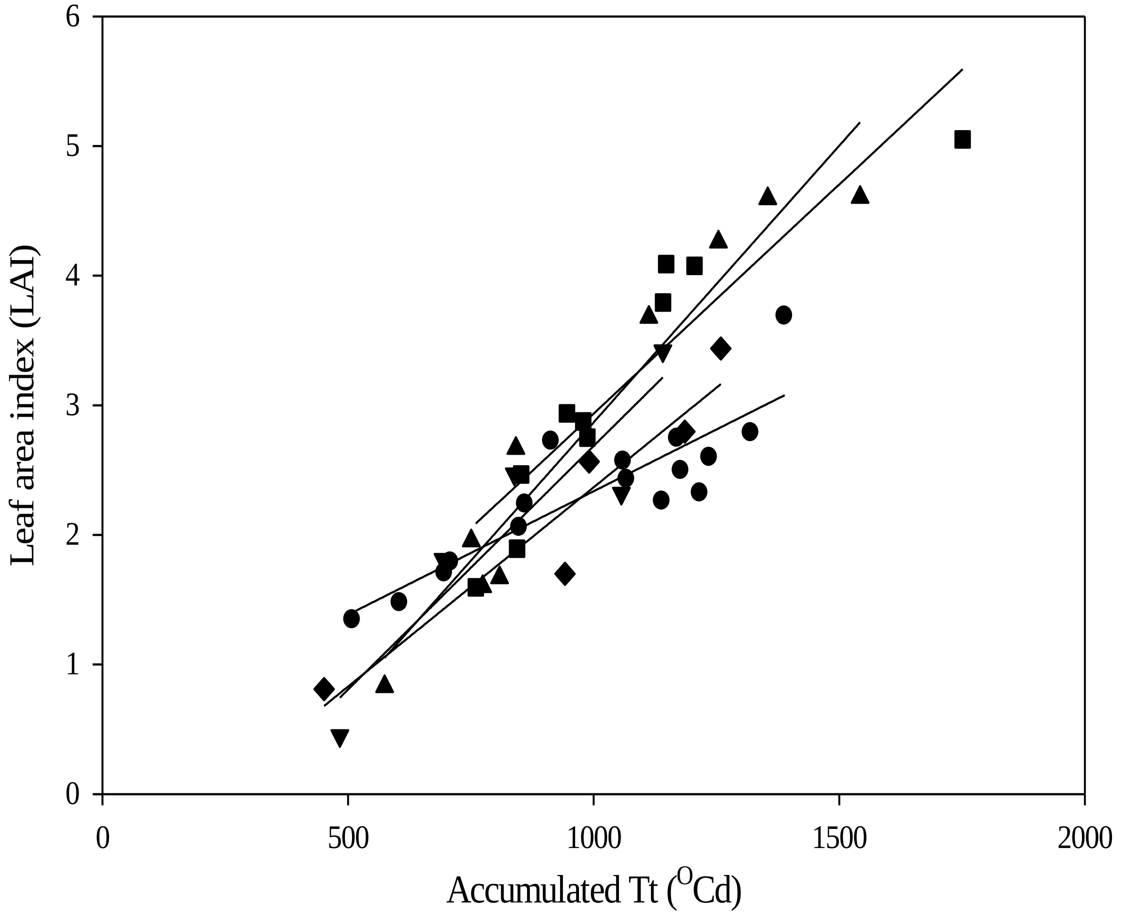

Figure 5: Leaf area index (LAI) against accumulated thermal time (Tt) with a base soil temperature of 0°C for Milton oat crops sown on 4 March (S_1) (●), 28 March (S_2) (■), 21 April (S_3) (▲), 12 May (S_4) (◆) and 3 June (S_5) (▼) in 2008 at Lincoln University, Canterbury, New Zealand. Regressions are:
S_1, y = 0.431 (± 0.28) + 0.002 (± 0.0003)x (R^2 = 0.76),
S_2, y = -0.601 (± 0.57) + 0.004 (± 0.0005)x (R^2 = 0.84),
S_3, y = -1.402 (± 0.45) + 0.004 (± 0.0004)x (R^2 = 0.92),
S_4, y = -0.708 (± 0.58) + 0.003 (± 0.0006)x (R^2 = 0.87),
S_5; y = -1.073 (± 0.79) + 0.004 (± 0 .0001)x (R^2 = 0.81).

Discussion

Early autumn sowing, on 4 and 28 March 2008, gave maximum growth rates of 71 kg DM ha^{-1} d^{-1} and 47 kg DM ha^{-1} d^{-1}, respectively. These results support those of de Ruiter *et al*. (2002) who reported that forage cereals (oats, triticale and barley) could give a yield of 50 to 60 kg DM ha^{-1} d^{-1} over winter from an early March sowing.

The maximum DM in S_1 (14,620 kg ha^{-1}) was lower than in S_2 (15,390 kg ha^{-1}) probably because of an outbreak of barley yellow dwarf virus in August and

September. The maximum yield, in this study, was slightly higher than the 10 t ha^{-1} reported by McDondald and Stephen (1979) and Jacobs *et al*. (2009) in New Zealand and Australia, respectively. The two New Zealand studies were similar. However, the Australian work examined whole crop cereal silage. In another study conducted from 1975 to 1977 in the Manawatu, New Zealand, Eagles *et al*. (1979) reported a higher mean yield of 16.3 t ha^{-1} DM of 4 cultivars of winter oats harvested in spring.

In most cases, an early autumn sown oat crop has a shorter emergence period and higher vegetative growth rate than oats sown in late autumn and winter. In this study, early autumn sown oats (S_1 and S_2) had higher winter growth rates than later sown oats. The differences in yield across the different sowing dates was associated with the early autumn sown oats receiving higher incident radiation and higher accumulated temperature sums over the duration of their growth. Both of these factors influence the rate of leaf appearance and canopy expansion.

The earlier sown oats achieved 90% light interception and $LAI_{(crit)}$ earlier than the later sown oats. The failure of later sown oats to obtain high yields was due to their low LAI and their delay in reaching canopy closure through most of the growing season. Canopy closure did not occur until the end of winter (S_3) or early October (S_4 and S_5). Low temperature reduced the rate of crop leaf appearance and expansion. Hay and Porter (2006) stated that the rate of leaf appearance in crop plants depended mainly on the temperature of the expanding leaves. This agrees with McMaster *et al*. (2003) who found temperature was the primary environmental factor controlling the phyllochron, or rate of leaf appearance in wheat (*Triticum aestivum* L.). However, after reaching LAI_{crit}, the growth rate of the later sown oats was rapid. This occurred in spring with high incident light and temperatures.

This study demonstrated the dependence of oat DM accumulation on the time available for growth between sowing and harvest. The determination of harvest date would depend on the purpose the crop was sown for, whether it was to be cut for green feed, grazed or ensiled. It has been reported that different times of harvest affect DM accumulation and are associated with a decline in nutritive value (metabolisable energy and crude protein content) of the forage (Filya, 2003; Jacobs *et al*., 2009). Late sowing (early June) resulted in low DM production because of the long duration to canopy closure followed by a shorter spring growth period. However, if the oats were sown too early, the yield may be reduced if barley yellow dwarf virus incidence was high as occurred in S_1 of this study.

Conclusions

Oats sown between early March and the middle of April reached canopy closure and therefore had longer before growth was limited by declining temperatures and radiation levels in the winter. Oats were ready for harvest in September or October as would be the case for late winter green feed or for making silage. The results highlighted the importance of selecting the appropriate sowing and harvest date for oats to produce a high DM yield. The choice of sowing and harvest times offers some flexibility to match with summer crops to maximise total annual yield.

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