

Dry matter accumulation of faba bean sown at different sowing dates in Canterbury

M.Y. Martini^{1,2}, B.A. McKenzie¹, D.J. Moot¹ and G.D. Hill¹

¹Faculty of Agricultural Sciences, Lincoln University PO Box 84, Canterbury, New Zealand

²Department of Crop Science, Faculty of Agriculture, University Putra Malaysia, 43400, Serdang Selangor.

Abstract

'Old New Zealand' faba beans were sown on five dates in the autumn and winter of 2008 and on three sowing dates in the autumn of 2009 at Lincoln University, Canterbury. The crops were sampled throughout their growing periods and a final harvest was completed from the middle to end of October in 2008 and in early December in 2009. Crops yield ranged from 4,420 to 21,340 kg DM/ha across all sowing and harvest dates. Low yield was related to disease outbreak, snow damage and failure to reach a critical leaf area index before winter. Declining temperatures slowed the rate of leaf appearance, especially in the late sown crops in 2008. This reduced the leaf area cover and therefore light interception through the winter and early spring. Faba bean reached canopy closure after 562-652 °Cd under favourable growing conditions. In this study, faba beans were shown to be a suitable crop for forage in Canterbury if sown from early March to late April. These crops could be harvested from late September to late November. This sowing to harvest window allows farmers to plan for late spring feed. Other options are possible if the crops are sown late and harvested for grain, however, there is a potential yield reduction with late sowing.

Additional keywords: *Vicia faba*, supplementary forage crop, canopy closure, harvest date

Introduction

Faba bean (*Vicia faba* L.) is a supplementary forage crop that can be grown in New Zealand (Clark *et al.*, 2007). It is a major source of protein, starch, cellulose and minerals from its mature seeds which can be used for human diets or animal feed. Faba bean seeds contain 27 to 34% protein with a high lysine content (Duc, 1997) and have a higher feed quality than grass and therefore may be preferred by livestock (Charlton and Stewart, 2006). Faba bean is categorised as an annual cool

season legume that could fit into a double cropping system in New Zealand, France and Spain (Taylor, 1980; Thom, 1980; Lloveras-Vilamanya, 1987). It has symbiotic nitrogen (N) fixing capability, which enables it to produce substantial yields without the addition of N fertiliser. This makes it an attractive break-crop in an arable rotation (Rochester *et al.*, 1998; Schwenke *et al.*, 1998).

In New Zealand faba bean is sown in autumn and harvested in winter or early spring. Alternatively it can be sown in

spring and harvested in late summer. Harvesting annual crops in winter or early spring would create an additional feed opportunity for dairy farmers if feed shortages occurred during early lactation (mid-July to September).

With autumn sown crops, the onset of cool autumn temperatures may slow the growth rate of the crops and therefore it is important to adjust sowing dates so that the impact of yield reduction on growth is minimised. Determination of optimum sowing time in autumn is important as declining temperatures may affect the final yield. Mechanisms for the yield decline are not well explained. However, cool temperatures during autumn and winter will restrict germination, reduce the rate of leaf appearance and expansion and consequently reduce canopy development and light

interception. The objective of this study was to determine suitable sowing and harvest dates to maximise the dry matter (DM) yield for faba bean crops sown in Canterbury and determine how the pattern of leaf area development influences productivity of the crop.

Materials and Methods

Two field experiments with an 'Old New Zealand' faba bean variety were established on Blocks H14 and I8 (43° 38' S, 172° 28' E) at Lincoln University, Canterbury in 2008 and 2009. Block H14 had been used for barley in 2007 while I8 had been in lucerne in 2007, followed by barley in 2008. The site was tested for minerals before site cultivation using a Ministry of Agriculture and Fisheries (MAF) soil quick test (Table 1).

Table 1: Soil test results from 2008 (0-75 mm) and 2009 (0-150 mm) at Lincoln University, Canterbury.

Year	pH	Olsen-P(µg/ml)	Ca	Mg	K	Na	Sulphate (µg/g)	Anaerobic Mineralisable N (kg/ha)
			-----me/100 g -----					
2008	5.9	23	6.20	0.85	0.33	0.15	2	42
2009	6.2	14	6.97	0.90	0.72	0.15	9	105

The experiment was located on a Templeton silt loam in 2008 (Udic Ustochrept, U.S. Soil Taxonomy) and a Wakanui deep silt loam (Aquic Ustochrept, U.S. Soil Taxonomy) in 2009 (Watt and Burgham, 1992). Faba beans were part of an experiment that included 'Milton' oats (*Avena sativa* L.), 'Feast II' Italian ryegrass and an intercrop of faba bean and oats. Data analysis was performed on the whole trial with other species treatments included in the design, but data for the faba bean alone is reported here.

The experimental design in both years was a split plot randomised complete block (with four replicates). Sowing date was the main plot and crop species comprised sub-plots. Faba beans were sown on five dates in 2008 (4 March, 28 March, 21 April, 12 May, 3 June) and three dates in 2009 (16 March, 16 April and 15 May). In 2008, there were 60 plots each 2.1 × 14 m, and in 2009, there were 48 plots of 6.3 × 10 m. Faba beans were sown with an Øyjord cone seeder at 60 plants/m² at a depth of 40 mm in 150 mm rows. In 2008, sulphur superphosphate was applied on 2 March at

200 kg/ha for the whole trial area and in 2009 a single application of 150 kg/ha of superphosphate was applied on 10 March also over the whole trial. No other fertiliser was applied.

Soil moisture content (SMC) was monitored every 7 to 10 days. Irrigation was applied when the SMC fell to 20% below field capacity as measured by a Hydrosense probe placed at 0.3 m depth in both years. Insects were controlled with Pirimor[®] 50 (a.i 500 g/kg pirimicarb) (250 g/ha), disease control was with Topsin[®] M-4A (a.i 400 g/l thiophanate-methyl) (2.5 l/ha), Chlorotex[®] (a.i 500 g/l chlorothalonil) (2 l/ha) and Bravo[®] (720 g/l chlorothalonil) at 2 l/ha. Weed control was with Glyphosate 450 (a.i 450 g/l glyphosate as the isopropylamine) applied at 2 l/ha before sowing and with Basagran[®] (a.i 480 g/l bentazone) (2 l/ha) post emergence. Hand weeding was carried out when necessary throughout the growing season.

Measurements

Dry matter yield

Above ground biomass was measured by taking duplicate 0.1 m² quadrats from the six central rows in each plot. Sampling was done at two to three week intervals in both experiments. For the final harvest duplicate 0.5 m² quadrats were used. Samples were weighed and oven-dried at 60°C to constant weight. In 2008, the crops were sampled at a different time for each sowing date. The final harvest dates were 13 October for the 4 March sowing date, 11 October for 28 March sowing date, and 25 October for the 21 April sowing date. For the 12 May and 3 June sowing dates, the final harvest was taken on 30 October 2008. In 2009, sampling was done sequentially for all three sowing dates until a final harvest on the 4 December.

Radiation interception and leaf area index (LAI)

In 2008, light interception and leaf area index (LAI) were measured using a plant canopy analyser LAI-2000 (LI-COR Biosciences, Inc., Nebraska, USA). Measurements were taken weekly from March to October, except in June, July and August when they were once every three weeks. In 2009, a Decagon AccuPAR model LP-80 PAR/LAI Ceptometer (Decagon Devices, Inc., Washington, USA) was used for light interception and leaf area measurement. The frequency of observations was similar to the first experiment.

Thermal time calculation

Thermal time was calculated after the base temperature (T_b) was determined ($T_b=2.4^\circ\text{C}$) by using a modified sine curve method to adjust for a symmetrical diurnal pattern (Equation 1) which is fitted to mean daily air temperature above T_b (Jones and Kiniry, 1986). Base temperature was determined using a linear regression analysis (Moot *et al.*, 2000). Temperature was interpolated into 8×3 -hour intervals to account for diurnal temperature fluctuations throughout a day. P is the period (1-8) for each interval during the day. Tt_{daily} was related to measured leaf area index for respective sowing date treatments.

$$Tt_{\text{daily}} = t_{\text{range_fract}} \times \text{diurnal range (Equation 1)}$$

where,

$$\sum t_{\text{range_fract}} = 0.92 + 0.0114 \times P - 0.07 \times P^2 + 0.005 \times P^3$$

for $P=1-8$ and

$$\text{diurnal range} = T_{\text{max}} - T_{\text{min}}$$

Data analysis

Statistical analyses were carried out using the GenStat (version 12.2, VSN International Ltd, U.K). A full split plot analysis of variance was used with sowing dates as main plots and crop species as sub-plots and four replicates in both of the experiments. Significant main effects and interactions were separated by Least Significant Difference (LSD) tests ($P=0.05$). Data of leaf area index were fitted using a sigmoid curve. For the regression analysis, all points up to maximum DM against thermal time were used for all sowing dates.

Results

Total dry matter accumulation over time

The patterns of total faba bean DM accumulated over time for all five sowing

dates in 2008 and three sowing dates in 2009 are shown in Figures 1a and 1b. In most cases, the curves fitted the measured DM yield closely. In 2008, the maximum TDM was obtained from the 4 March sowing (11,410 kg/ha) when harvested at 223 days after sowing (DAS) while the last two sowing dates gave the lowest yields (Figure 1a). In 2009, crops sown on 16 April produced higher maximum TDM of 21,340 kg/ha (218 DAS) compared with 16 March sowing with maximum TDM yield of 19,700 kg/ha (239 DAS). Faba bean sown on 15 May yielded the lowest with 15,250 kg/ha at 203 DAS. In comparison between the sowing dates of 4 March in 2008 and 16 March in 2009, DM yield in 2009 was higher (2,880 kg/ha) than maximum TDM yield in 2008 when harvested at a similar date (Figure 1a and 1b).

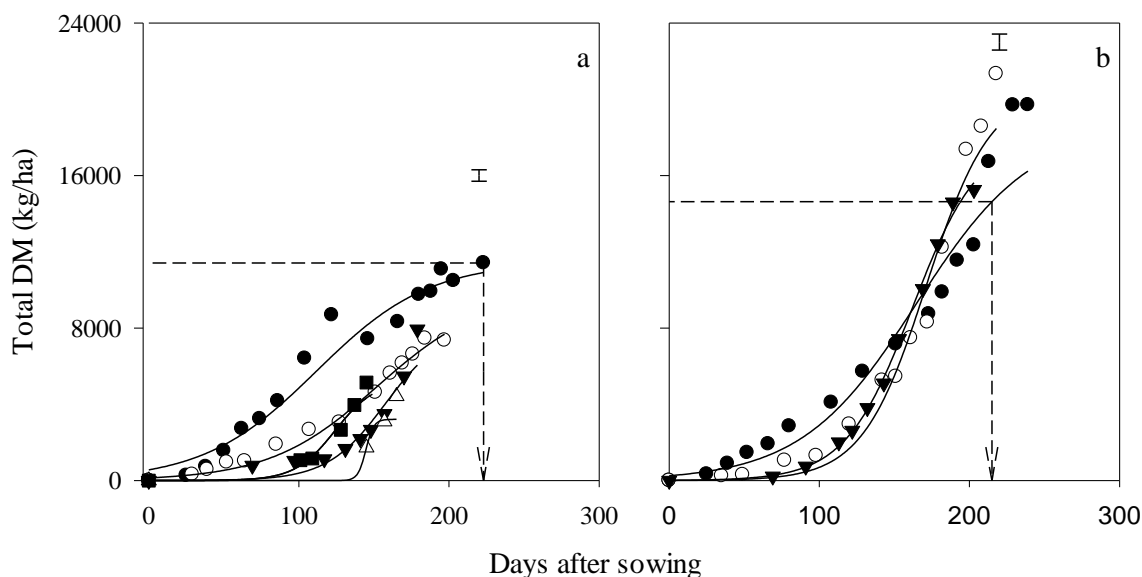


Figure 1: Total dry matter (DM) accumulation to maximum TDM from days after sowing in 2008 (a) sown on 4 March (●), 28 March (○), 21 April (▼), 12 May (Δ) and 3 June (■) and in 2009 (b) sown on 16 March (●), 16 April (○) and 15 May (▼) at Lincoln University, Canterbury, New Zealand. Error bars represent standard error of mean (SEM) of maximum total DM.

Yield was influenced by crop duration and mean growth. In 2008, crop duration ranged from 37-185 days for 3 June and 4 March sowing dates, respectively while mean growth rate ranged from 105 kg/ha/d to 58 kg/ha/d for the same sowing dates, respectively. In 2009, crop duration ranged from 112 days for 15 May sowing to 173 days in 16 March sowing. Corresponding

mean growth rates were 130 kg/ha/d and 103 kg/ha/d, respectively. The results also indicated accumulated DM was closely correlated with accumulated thermal time for all sowings. Faba bean accumulated 7 to 14 kg DM/°Cd when sown in early autumn to early winter in 2008. Accumulated DM of 12 to 15 kg/°Cd occurred when sown in early to late autumn in 2009 (Figure 2).

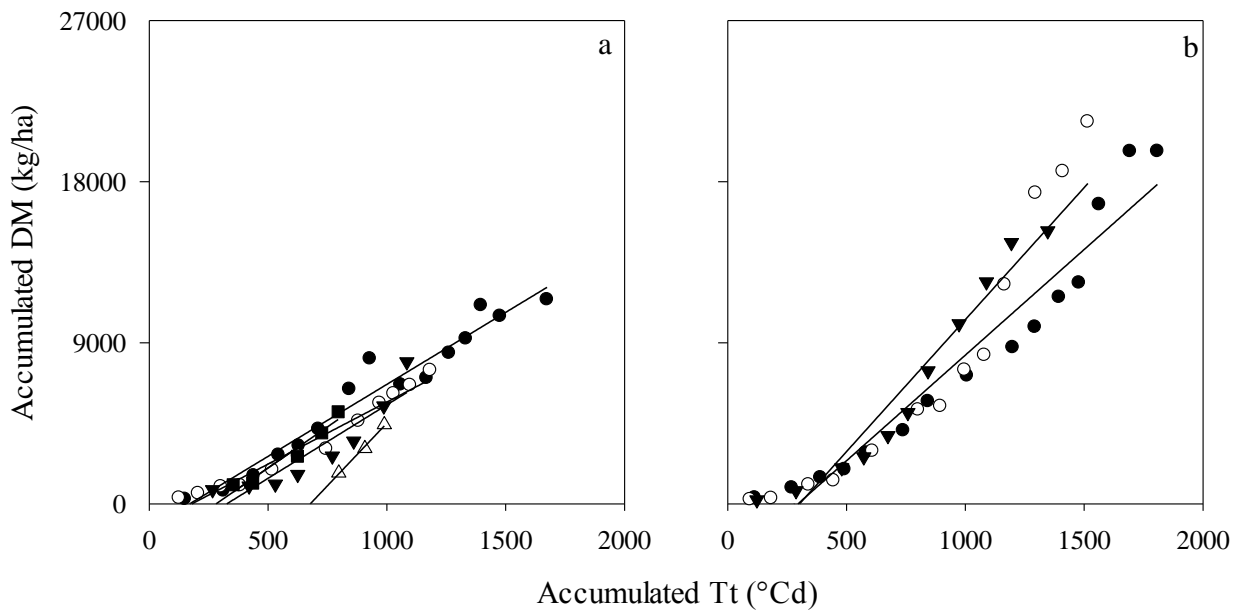


Figure 2: Dry matter accumulation against accumulated thermal time (Tt) ($T_b=2.4^{\circ}\text{C}$) in 2008 (a) sown on 4 March (●), 28 March (○), 21 April (▼), 12 May (Δ) and 3 June (■) and in 2009 (b) sown on 16 March (●), 16 April (○) and 15 May (▼) at Lincoln University, Canterbury, New Zealand. The regressions are:

$$\begin{aligned}
 \text{4 March,} & \quad y = -1368(\pm 510) + 8.04(\pm 0.49)x \quad (R^2=0.95), \\
 \text{28 March,} & \quad y = -1243(\pm 306) + 6.93(\pm 0.40)x \quad (R^2=0.96), \\
 \text{21 April,} & \quad y = -2678(\pm 1095) + 8.20(\pm 1.47)x \quad (R^2=0.81), \\
 \text{12 May,} & \quad y = -9482(\pm 967) + 13.9(\pm 1.07)x \quad (R^2=0.98), \\
 \text{3 June,} & \quad y = -2578(\pm 761) + 9.17(\pm 1.24)x \quad (R^2=0.92), \\
 \text{16 March,} & \quad y = -3489(\pm 965) + 11.7(\pm 0.85)x \quad (R^2=0.93), \\
 \text{16 April,} & \quad y = -4455(\pm 1534) + 14.7(\pm 1.62)x \quad (R^2=0.87), \\
 \text{15 May,} & \quad y = -3956(\pm 1024) + 14.1(\pm 1.21)x \quad (R^2=0.93).
 \end{aligned}$$

Intercepted radiation and critical leaf area index

The relationship between the fraction of radiation intercepted and LAI for faba bean

is shown in Figure 3. The mean critical LAI (LAI_{crit}) at which 95% of intercepted PAR was calculated to be 3.48.

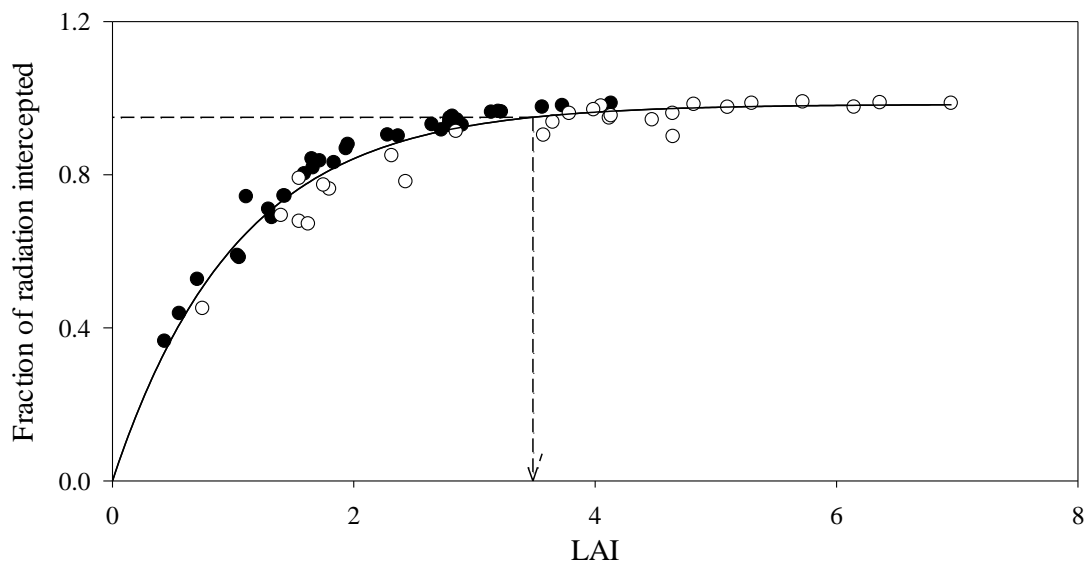


Figure 3: Fraction of radiation intercepted against leaf area index (LAI) of faba bean sown on five sowing dates in 2008 (●) and three sowing dates in 2009 (○) at Lincoln University, Canterbury, New Zealand. The solid line is the fitted exponential curve, $y=0.98(1-e^{-0.97x})$ ($R^2=0.96$). The dashed line represents the 95% photosynthetically active radiation (PAR) intercepted and the critical leaf area index (3.48).

Leaf area index

The LAI growth responses to thermal time showed differing responses for differing sowing date and years (Figure 4). The maximum leaf area index (LAI_{max}) was higher in earlier sowings in year one, but was lower in respective sowings in year two. The LAI_{max} ranged from 1.9 to 4.1, for crops sown in 2008 and was significantly higher in the second year (5.8-7.0). There was a sowing date effect on thermal duration required for the crops to achieve maximum leaf area index. The earliest sown (4 March) crop reached the LAI_{crit} in early September after 1297 °Cd, while the crop sown on 28 March reached LAI_{crit} in late

August after 867 °Cd. It was not clear why the early sown faba bean appears to develop more slowly than the later sown crop. In 2008, the last three sowings of faba bean did not reach LAI_{crit} .

In 2009, the extended crop duration meant the maximum LAI ranged from 5.7 to 7.0. Faba bean sown on 16 March reached LAI_{crit} by the end of autumn (May) after 562 °Cd. In contrast faba bean sown on 16 April, reached the LAI_{crit} at the end of winter (August) with an accumulated thermal unit of 652 °Cd. For the last sowing date (15 May), 570 °Cd was required to reach the LAI_{crit} which was attained in early spring (mid-September).

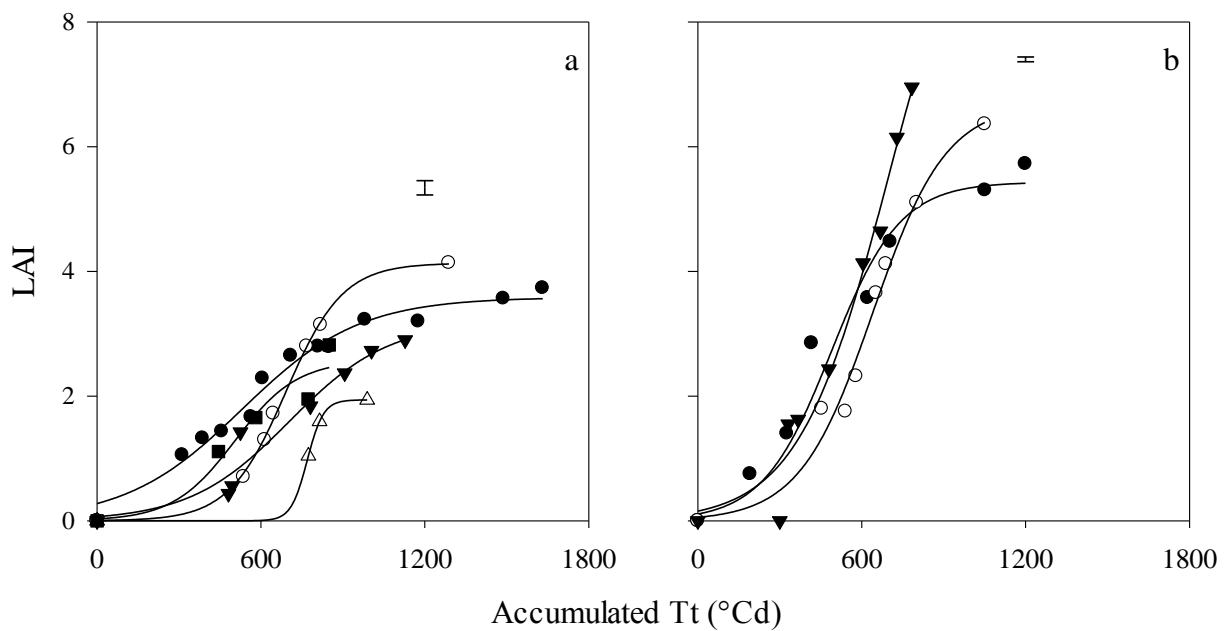


Figure 4: Leaf area index (LAI) against accumulated thermal time (Tt) ($T_b=2.4^{\circ}\text{C}$) in 2008 (a) sown on 4 March (●), 28 March (○), 21 April (▼), 12 May (△) and 3 June (■) and in 2009 (b) sown on 16 March (●), 16 April (○) and 15 May (▼) at Lincoln University, Canterbury, New Zealand. Error bars represent standard error of mean (SEM) of maximum leaf area index. Lines are fitted sigmoid curves.

Discussion

Faba beans grown over two seasons (2008 and 2009) with multiple sowing dates (Figures 1a and 1b) showed widely differing growth responses. Yields achieved were strongly driven by sowing date. Opportunity for achieving acceptable yield can be linked to a sowing window whereby sufficient thermal time was accrued before growth limiting temperatures occurred in late autumn (Figure 2a and 2b). The data in Figure 2 covered five sowing dates in 2008 and three sowing dates in 2009 and therefore represented a wide range of sowing options.

Aside from temperature driven biomass production there were other biotic factors that affected the growth responses. Significant growth reductions occurred in sowing dates one in year one due to

widespread incidence of chocolate spot (*Botrytis fabae*), and Ascochyta blight (*Ascochyta fabae*) which started in April 2008 and a severe outbreak of rust (*Uromyces viciae-fabae*). Furthermore, for the 21 April 2008 sowing date, some plots were affected by a wilt caused by *Fusarium oxysporum*. This resulted in about a 67% higher yield of crops sown on 16 April 2009 compared with 21 April 2008 despite there being only a six day gap between the sowing dates. Yield for the 15 May sowing date was only 4% less than the crops sown on 21 April. In general, yield for equivalent sowing dates in year two were higher than in the previous year. There was a yield difference 4,630 kg/ha between 12 May sowing in 2008 compared with 15 May sowing in 2009. The crop in 2008 had poor establishment as a result of bird damage at

the seedling stage. Furthermore, yields in 2008 were affected by snow falls in early June and July 2008 resulting in lodging and subsequent frost damage. Damage to main stems was partially compensated by growth of branches from the base of the main stem. Overall, the experience in 2008 indicated faba bean was an agronomically challenging crop to grow particularly in a difficult growing season

The differences in yield between years could further be explained by the higher incident radiation received and higher temperatures over most of the growing season for crops sown in early autumn compared with late autumn and winter sowings. Both of these factors affected the leaf appearance and canopy expansion.

The duration of crop growth is an important determinant of crop yield as it largely determines the total amount of radiation intercepted during the growth period. Sowing of faba bean could be delayed until middle of April and harvested in late November to produce the highest yield. This option will allow growers to sow kale or another summer brassica in December. Sowing of faba bean could also be delayed until late April and up to 7,930 kg DM/ha achieved, with a harvest in the middle of October. However, there is a risk of wilt. If faba beans are sown in May, the crop would possibly be exposed to bird damage when germination and emergence are slow. Late sowing in early June is not a viable option as soil conditions are often not suitable for cultivation prior to sowing and there is a strong prospect of low DM production because of the inability to achieve ground cover. Late autumn and winter sowing invariably means crops will not achieve their LAI_{crit} , with cold temperatures limiting the rate of leaf area expansion.

This study showed that faba bean could be sown in early March and harvested in late September or in the middle of October for a late winter green feed or for making into silage. This maturation time would allow a following maize crop sown in November with an average faba bean yield of at least 11,250 kg/ha. However, the faba bean would be at risk of leaf loss from chocolate spot, *Ascochyta* blight or rust.

This study showed that faba bean DM yield was strongly influenced by date of sowing and harvest date. Determination of the most suitable sowing and harvest date depends on whether the crop is to be cut for green feed, grazed or ensiled. It also depends on the choice of potential summer crops (maize or kale) to be sown after harvest of the faba bean.

Conclusions

Faba bean can be sown from early March to late April and harvested as early as late September and toward late November for high productivity. However, choice of sowing date affects the timing of yield accumulation. Delaying harvest date to late November would allow summer crops such as kale or rape to be sown in the middle of December. Later sowing in May towards early June increases the risk of crop failure and inability to reach canopy closure. Low yields are likely from late sowing with low temperatures causing slow leaf area growth. Large differences in DM yield occurred over the range of sowing dates (early March-early June). Late autumn and winter sowings exposed crops to severe climatic events and damaging biotic factors. These results highlight the importance in determining suitable sowing and harvest dates in order to obtain high DM yields at specific crop maturity dates.

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