Effect of sowing date on plant count, true-leaf growth stage and vernalisation of fodder beet and sugar beet

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Abstract

The effect of date of sowing on plant population, true-leaf growth stage, and vernalisation impact was investigated in a trial in 2015 in Canterbury. Fodder beet and sugar beet (*Beta vulgaris*) were sown at six different sowing dates (mid- and late-September, mid- and late-October and mid- and late-November) at rate of 100,000 and 110,000 seeds/ha, respectively. Higher plant populations were found in late-November sowing for fodder beet in comparison to the earliest sowing (81,000 versus 45,000 plants/ha). A median true-leaf growth stage eight on fodder beet plants was reached faster at the late-October (45.5 days), mid-November (44 days) and late-November (43.5 days) sowings, compared with the earlier sowings (mid-September: 58.5 days; late-September: 56.2 days; and mid-October: 52 days). For sugar beet plants, a true-leaf growth stage eight was reached faster in late-November and late-October than plants from mid-September, late-September, mid-October and mid-November sowings. Thermal time to reach the median true-leaf growth stage eight was calculated for each cultivar at each sowing date, and differed between both sowing date and cultivar. The highest and the lowest thermal time calculated for the true-leaf growth stage eight was in late-November (520°C for fodder beet and 497°C for sugar beet) and late-October (456°C for fodder beet and 409°C for sugar beet), respectively. The impact of the lower temperature in the early sowing had a greater impact on vernalisation on the fodder beet crop with a calculated number of 83 bolters/ha. These results indicate clear differences between date of sowing for plant populations and time to true-leaf growth stage achievement, and between cultivars the differences in vernalisation demonstrates the genetic selection of cultivars can substantially reduce this occurring with earlier sowings dates.

Additional keywords: *Beta vulgaris*, germination rate, true-leaf growth, sowing date

Introduction

In the last decade the area of fodder beet and sugar beet sown in New Zealand has grown exponentially, from less than 500 hectares in 2006 to above 45,000 hectares in 2016.This has been driven by the increasing use as a winter crop and a supplement for lactating dairy cows, as a finishing diet for beef cattle and deer, and as an additional forage crop for sheep production (Gibbs *et al*., 2015). While beets crops have higher per hectare production costs in comparison with other winter crops, the high yields (20-30 t DM/ha) makes the crop an inexpensive option for dairy and beef feeds (Gibbs, 2014). Maximised potential of beet yields involves paddock selection, soil preparation and agronomic best practice, but sowing date is also an important consideration.

When water and nutrients are not a limitation, early sowing dates are an opportunity to increase potential crop yields by increased thermal time accumulation (sum of daily (average temp - base temp) and light interception (sunlight) (McKenzie *et al*., 2008). However, caution needs to be taken with early sowing dates in beet crops as this can result in vernalisation (premature reproductive stage) of the beet due to the effect of sustained low temperatures. If soil temperature is lower than 10°C a slower germination rate and plant growth can also occur, which will impact on crop yield and weed growth due to open crops (Scott, 1971). Conversely, sowing too late (mid-December) has the potential to encounter soil moisture deficits if water is a limitation, which can affect establishment of the crop and consequently crop yield (Martin *et al*., 1982).

In Canterbury, New Zealand, beets are currently sown from early October through to mid-December, but earlier sowing has been attempted. While there have been studies on the interaction of sowing date with beet plant population internationally and dated information in New Zealand (Scott, 1969; Scott *et al*., 1971; Martin *et al*., 1983), there are limited data for sowing date effects under current New Zealand agronomic approaches. There is a need for data on the impact of sowing dates on plant count (establishment), growth stage (for canopy closure), and vernalisation under current agronomic approaches in the New Zealand environment. The objective of this study was to investigate the effects of a range of six sowing dates on these parameters in the Canterbury area for fodder beet (LIFTA™) and sugar beet (SUGA™) cultivars.

Materials and Methods

Site, cultivars and establishment

This study was carried out on a commercial farm located in Ashburton (43° 80' S, 171° 58' E) with Lismore stony and sandy shallow silt loam soils, in the 2015-2016 season. Soil preparation was carried out before the first sowing date with a pre-planting base fertiliser (76 kg N/ha, 200 kg K/ha, 20 kg B/ha, 100 kg Mg and S/ha and 50 kg Na/ha). Thereafter, a second (N and P) third (K, N and S) and fourth (N) fertiliser application was carried out on 15 September, 15 November and 15 December. Seeds were sown with a precision drill at 15 mm depth (Kvernland Accord Monopil SE 12 row drill) with 500 mm drill spacing. The cultivars included in the trial were Seed Force (Christchurch, New Zealand) fodder beet variety SF LIFTA® (sown at 100,000 seeds/ha) and sugar beet variety SF SUGA® (sown at 110,000 seeds/ha). Irrigation was applied eight times between 1 November and 10 April at rate of 15-30 mm, using a valley lateral irrigator.

Trial design

Trial design was four blocks of a split plot design, with the six sowing dates (mid-September (14th), late-September (27th), mid-October (12th), late-October (28th), mid-November (9th), and late-November (23rd)) being the main plot treatments and the two cultivars (Fodder beet, Sugar beet) the sub plot treatments. Each block was 50 m long and 144 m wide, and each main plot was 12 m wide.

Measurements

Weather conditions

Climatic conditions (soil and air temperature at the time of planting, sunlight, humidity and wind speed) were obtained from Lismore-NIWA weather station at each observation date of plant population, growth stage (GS) and vernalisation assessment. Using the daily mean air temperature (°C) recorded the accumulated thermal time for each GS (2, 4, 6 and 8) was calculated with a base temperature of 3°C.

Plant population and growth stages

Plant population (Figure 1a,b) and GS (Table 3) in both cultivars were measured every two-three days from one-week post-planting through to until the median of plants reached the eight true-leaf stage for each sowing date. Five 2 m drill lengths were pre-selected and labelled in each sub-plot, following planting, using randomly generated co-ordinates. For plant population (plant emergence), the number of plants in each of 2 m drill length was counted at each observation day and their leaf GS was recorded using stages identification (Table 1).

Bolters

Bolting plants (premature seed head production) were assessed at each observation day of plant population and GS measurements. The number of bolters including information describing the bulb colour was recorded to distinguish “weed beet” bolters from cultivar specific (‘true’) bolters (vernalisation effect); after identification and recording these were pulled out to prevent repeat recordings.

Statistical analysis

Data analyses for plant population, time to reach GS 2, 4, 6 and 8 (using the median of plants), bolter numbers and thermal times were carried out using a split plot experimental design (with six sowing dates as main plots treatments and two cultivars as subplot treatments) on GenStat version 16.1 (VSN International Ltd, UK) with randomized complete block with 4 replicates.

Table 1: Growth stages (GS) of beet plants.

GS	Description
0	Cotyledons emerged and no evidence of first or second leaf
0.1	Cotyledons and first and second leaf just visible
0.5	Cotyledons present and at least 50% of next leaves unrolled
0.9	Cotyledons present and at least 90% of next leaves unrolled, but not completely
2	Two leaves unrolled and third not visible
2.1	Two leaves unrolled and third leaf just visible
2.5	Two leaves unrolled and third leaf at least 50% unrolled
2.9	Two leaves unrolled and third leaf 90% unrolled
3.0 - 8.9	Beyond 2.0 leaf stage, two or more developing leaves are always present

Results

Weather data

Table 2 shows the mean of the 7 days before the actual sowing date of the weather data recorded. The lowest soil temperature was registered on the day of mid and late-September sowings (6.2°C and 7.9°C, respectively) whereas mid and late-October and mid and late-November sowing dates had higher soil temperature (12.2°C-13.1°C: Table 2). The lowest and highest (3.1°C and 10.5°C) air temperatures were registered on the day of late-September and mid-October sowings, respectively. Wind speed was highest (37.1 km/h) during mid-October sowing and lowest (8.5 km/h) at the mid-September sowing date. However, locational recorded wind speed reached values of 72.3 km/h in the period of early October.

Table 2: Weekly mean of soil and air temperature, sunlight, humidity and wind speed before each sowing date.

Sowing date	Soil temperature (°C)	Air temperature (°C)	Sunlight (MJ/m2)	Humidity (%)	Wind speed (km/h)
mid-September	6.2	4.2	13.6	71.6	8.5
late-September	7.9	3.1	14.3	79.5	22.0
mid-October	12.2	10.5	21.1	51.5	37.1
late-October	12.6	7.7	16.8	65.6	31.2
mid-November	12.7	7.7	15.4	72.7	24.9
late-November	13.1	8.9	23.3	66.3	10.4

Plant population

Sowing date had significant effect ($P<0.05$) on plant population in both fodder beet and sugar beet crops. For fodder beet, mid-September and late-November sowings had the lowest (45000) and highest (81000) plants per hectare at the final observation, and significant differences ($P<0.05$) were found between late-November and the other sowing dates with exception of mid-October (69500 plants). Plant count for mid and late-September started from observation number 3 and 4 respectively, whereas for the other four sowing dates plant count started from observation number 2 (mid-October $P<0.05$). At observation number 5, mid-September and mid-November had less plants ($P<0.05$) than late-November sowing. But at observation 6, mid-October had the lowest plant count among sowing dates and significant differences ($P<0.05$) were found between mid-October plant count and late-November. From observation number 7 onwards, late-November plant count was significantly higher ($P<0.05$) than the other sowing dates with the exception on observation number 8 in which late-September had a spike of plant count.

For sugar beet (Figure 1b), plant count started at the observation number 2 with the exception of mid and late-September where plant count started at observation number 4 and 3, respectively. At observation number 3, late-September had higher ($P<0.05$) plant population than late-October and mid and late-November. At observation number 4, mid-September had significantly ($P<0.05$)

less plants than late-September and late-November. However, at observation number 5 late-October had less (P<0.05) plants than the late-September and late-November. At observation 6, late-October had significantly (P<0.05) less plants than late-September and mid and late-November. At observation number 7, 8, 11 and 12 late-October had significantly (P<0.05) less plants than the other five sowing dates. However, at observation number 9, 10, 13, 14 and 15 late-October had significantly (P<0.05) less plants than late-September, mid-October, and mid and late-November. On the last observation number late-October had significantly (P<0.05) less plants than late-September, mid-October and late-November.

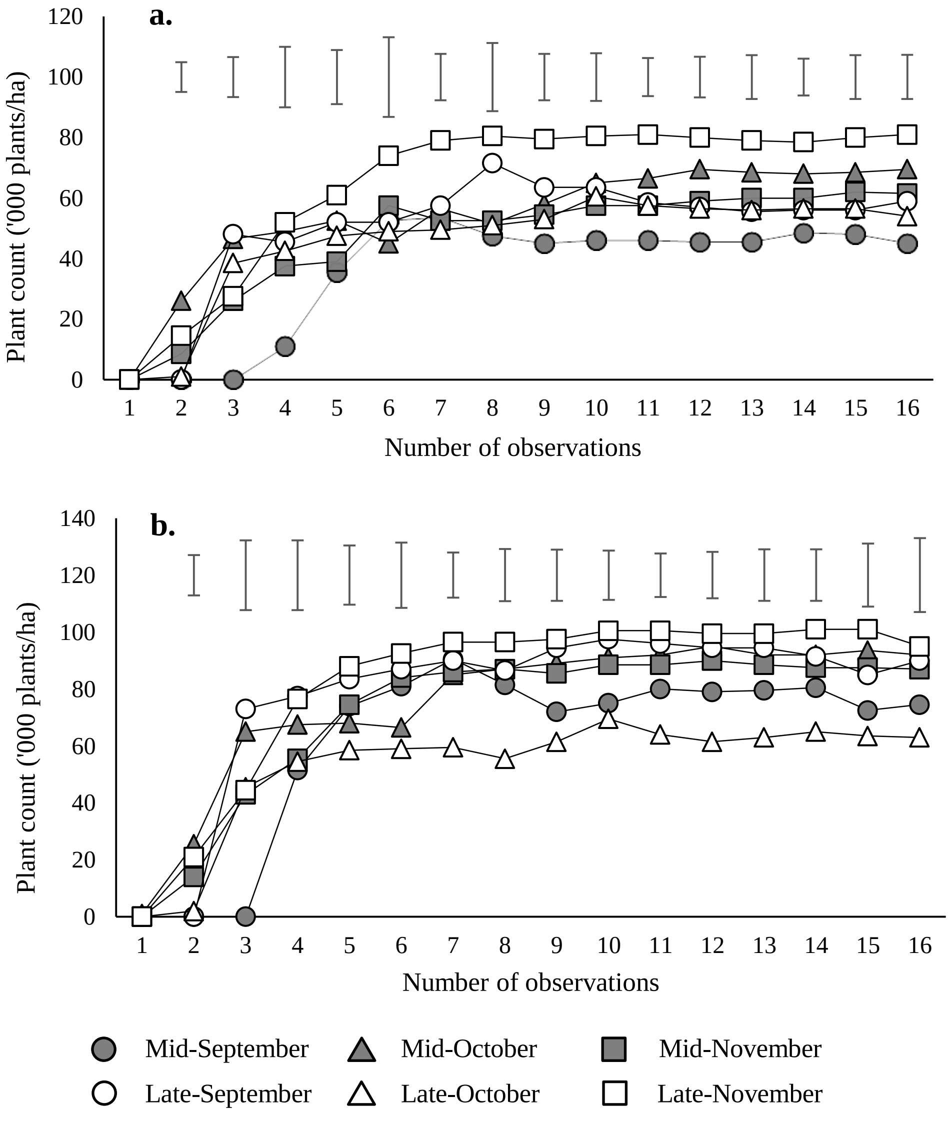

Figure 1: Effect of sowing date (mid- and late-September, mid and late-October and mid and late-November) on (a) fodder beet and (b) sugar beet plant count ('000 plants/ha). Bars represent the least significant differences (LSD 5%).

Median plant (leaf) growth stage

Plant GS was assessed until half the plants in any plot reached the eight true-leaf stage. The time required for this varied among sowing dates, being longer in mid-September (fodder beet 58.5 days; sugar beet 55.8 days) and shorter in late-November (fodder beet 43.5 days; sugar beet 41.2 days). For fodder beet plants, earlier sowings (mid-September, late-September and mid-October) required more (P<0.05) days to achieve this compared with later sowing dates (late-October, mid-November and late-November).

A similar trend was observed for sugar beet, with mid and late-September sown plots taking longer than those of mid-October and mid-November, and all of these required more time (P<0.05; Table 3) than plants from late-October and late-November sowing to reach GS 8.

Table 3: Mean number of days taken for median plants to reach growth stage (GS) 2, 4, 6 or 8 for each sowing date, for both fodder beet and sugar beet.

	Number of leaves							
	Fodder beet				Sugar beet			
Sowing date	GS2	GS4	GS6	GS8	GS2	GS4	GS6	GS8
mid-September	28.5	41.0	50.0	58.5	28.0	39.0	47.2	55.8
late-September	25.2	37.2	46.0	56.2	24.0	34.2	42.0	52.5
mid-October	25.0	39.2	45.0	52.0	24.2	37.8	42.5	46.5
late-October	26.5	32.8	40.5	45.5	26.0	30.0	38.0	41.5
mid-November	23.0	32.8	35.2	44.0	25.8	32.0	38.5	45.0
late-November	24.8	33.5	40.0	43.5	23.2	32.2	35.5	41.2
LSD (5%)	1.0	4.0	6.2	5.0	2.6	2.3	2.9	3.7

Thermal time

Figure 2 shows the accumulated thermal time (°C) required for the median of plants (leaf) of fodder beet (a) and sugar beet (b) to reach a GS 2, 4, 6 and 8. The lowest and highest thermal time in fodder beet GS2 was calculated for mid-September (227°C) and late-November (312°C) sowings; similar thermal times were seen between late-September and mid-November (240°C and 249°C, respectively), and mid-October and late-October (213°C and 212°C, respectively), but among these there were significant differences between the former and latter. Fodder beet thermal time for GS4 was significantly higher (P<0.05) on late-November (407°C) sowing than the others sowing dates with the exception of mid-November (368°C). For GS6, thermal time was higher (P<0.05) in late-November (485°C) sowing when compared with the other five sowing dates (<406°C) and in GS8 the thermal time was lower in mid-September and late-October (462°C and 456°C, respectively) and higher in late-November (520°C; P<0.05). For sugar beet the calculated thermal time for GS2 was much higher in mid and late-November (282°C and 303°C, respectively) than the other four sowing dates (P<0.05). For GS4 late-October had the lowest thermal time (210°C) and late-November the highest

(393°C) followed by mid-November (362°C). In GS8 thermal time was higher in mid and late-November (428°C and 425°C, respectively) than the other four sowing dates ($P<0.05$) and similar pattern of thermal time was observed for GS8 ($P<0.05$).

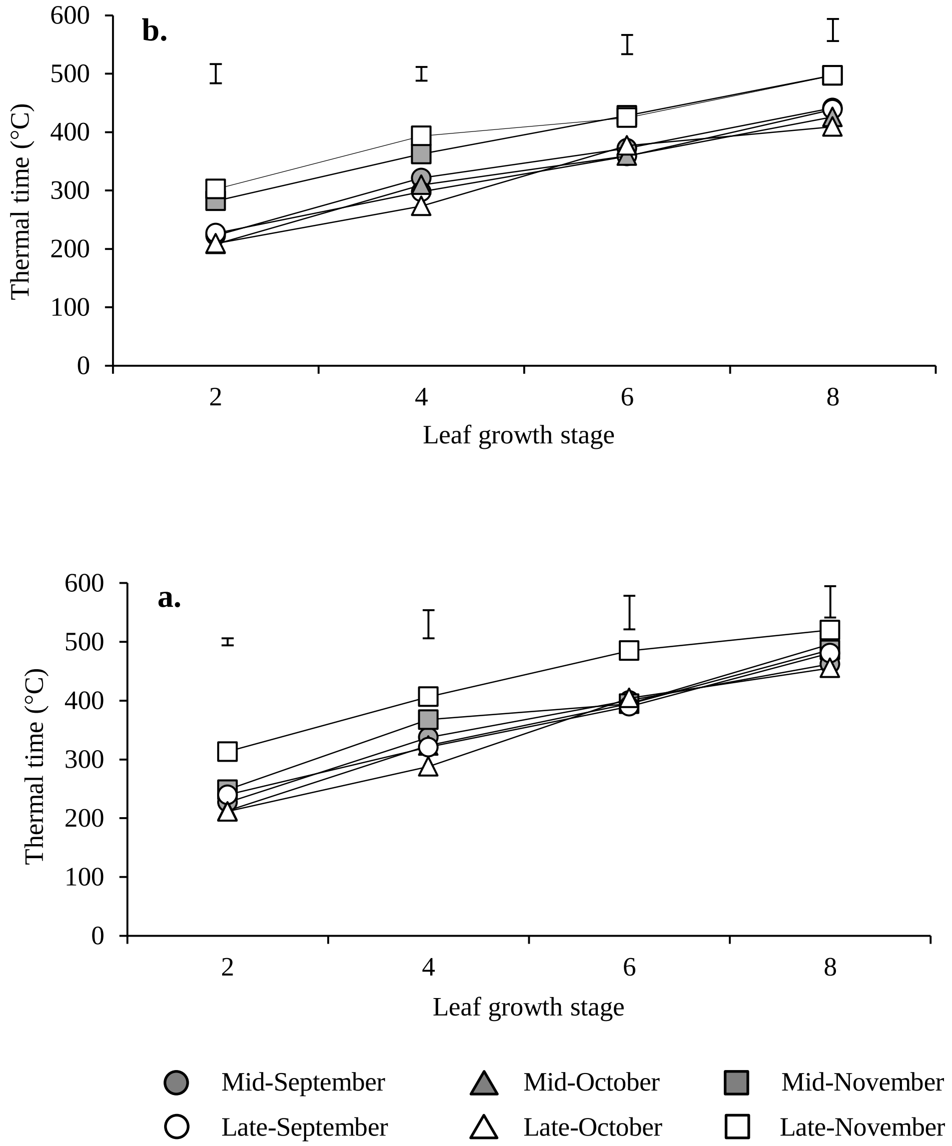

Figure 2: Mean thermal time required for the median of (a) fodder beet and (b) sugar beet plants to reach leaf growth stage 2, 4, 6 and 8 for the different sowing dates. Bars represent the least significant differences (LSD 5%).

Bolters

Early sowing (mid-September) had a higher number (83/ha) ($P<0.05$) of true bolters compared with the other five sowing dates on the fodder beet crop (50, 21, 17, 8 and 0/ha for mid-September, late-September, mid-October, late- October, mid-November and late-November, respectively; Table 4).

Table 4: Mean number of true bolters per hectare at each sowing date.

Sowing dates	Fodder beet	Sugar beet
mid-September	83.3	8.1
late-September	50.0	0.0
mid-October	21.7	0.0
late-October	16.7	5.0
mid-November	8.3	0.0
late-November	0.0	0.0
LSD (5%)	40.33	-

Discussion

In this study a significantly ($P<0.05$) higher plant population for the fodder beet crop (germination and establishment) was observed in the latest sowing (late-November) followed by mid-October sowing (Figure 1). For the sugar beet crop the effect of sowing date on plant population was less marked as by the end of the observation period all the sowing dates, with the exception of late-October ($P<0.05$), had a similar plant count (Figure 1), and it is not clear why this exception occurred, as it did not appear to be associated with soil temperature, ambient temperature or wind speed. Similar effects of fodder beet sowing dates on plant population in Canterbury were reported by Martin *et al.* (1982), where in three of the four experimental sites of their study late-October and late-November had significantly higher plant population than in early-September and late-September/early-October sowings. McCormick and Thomsen (1983) also reported higher plant population in late-September and late-October when compared with late-August and early-December, for crops grown in the Waikato region. They suggested that changing soil moisture profiles, adverse effects of sprays, and an inexplicably low establishment of beet crops in the trial years may have influenced this result. It is recognised that population increases may not correspond with crop yields. However Scott (1971), in the South Island, compared crop yields, rather than populations, with different sowing dates. Scott (1971) reported an advantage to mid-spring sowing, with mid-October sowing associated with higher fodder beet yields than early December sowing when weeds were controlled (22 versus 12 t DM/ha, respectively). In contrast, earlier work (Scott 1969) showed little differences in crop yield between different sowing dates.

In this study, neither field germination rates nor causes of plant death were assessed, so the cause of lower plant populations was not established. There are extensive reviews of the influence of temperature, soil moisture, osmolarity and photoperiod on beet germination, early vigour and plant establishment (Jarfarnia *et al*., 2013; Hay *et al*., 2014; Singh *et al*., 2015), and while all of these are dynamic across the sowing periods reported in this paper, the effects of these could not be conclusively determined in this work. However, the results of this study may provide some suggestion that soil temperature is a leading influence in the reported population differences, by impacting seed activation and metabolism, as evidenced by the clear increase in true bolters seen with the colder temperatures of the earlier sowing dates.

However, there is also a local factor that could be influential, the spring equinox wind systems that deliver strong westerly wind from the southern ocean (Titheridge, 1993). The relative fragility of early beet plant growth, up to a month post germination, to seasonal winds has been understood in beet growing systems internationally for many years (Nuckols, 1951), where plants can be ‘sand blasted’, lifted, or buried by moving soil. The recorded wind events in this trial (Table 2) would correlate with the timing of susceptible early plant growth stages, and may account for the population impact. The differences in soil temperature at sowing (at 9 am and 10 cm depth) may also partially explain the observed differences in populations between sowing dates, as this can influence both germination and establishment (Durra *et al.,* 2015). The weekly mean of soil temperature before sowing for mid and late-September was 6.2±1.2°C and 7.9±1.1°C, respectively, while the weekly mean soil temperatures before the later sowings ranged from 12.2±1.2°C for mid-October to 13.1±0.7°C for mid-November sowings.

These population differences due to different sowing dates varied between fodder beet and sugar beet (Figure 1) and could be due to higher seed sowing rate for sugar beet (100,000 seeds/ha for fodder beet and 110,000 seeds/ha for sugar beet), but the generally lower germination percentage of the fodder beet in repeated assessments (data not shown) may also be involved. The less vigorous germination of the fodder beet may also render it more susceptible to the influences of temperature, light and wind damage detailed above.

Later sowing dates (fodder beet and sugar beet) had higher calculated thermal time (Figure 2) than earlier sowings for recorded median GS of the plants, especially the eight-true leaf (Table 3). The shorter calendar days to a given GS with later sowing is consistent with previous reports (Martin *et al*., 1982), and while it is generally accepted that thermal time is constant for a species to reach a given GS, there are important influences on this process (Bonhomme, 2000). Morrison and McVetty (1991) used controlled environments of different temperatures to determine the thermal time of brassica development. Morrison and McVetty (1991) reported that the leaf appearance interval was not constant with regard to thermal time between the different growing temperatures studied. Collie and McKenzie (1998) in a New Zealand study of forage brassicas demonstrated a broadly consistent thermal time in development stages, concluding this was the principal factor regulating growth. However, Morrison and McVetty (1991) also reported the thermal time to leaf appearance differed between different growing dates, which suggests some non-linearity between temperature and plant development. In a further New Zealand brassica study, Andreucci *et al.,* 2016 also demonstrated a non-linear relationship between plant development and thermal time with different ambient temperatures, and linearity is discussed by Bonhomme (2000) as a limitation to the thermal time concept.

Other influences on the use of thermal time as a model for plant development are the necessity of excluding other growth limitations (e.g. soil moisture) and the manner in which temperature data is obtained (Jamieson *et al.,* 1995; Moot *et al.,* 2000). For example, it is possible for temperature differences between the plant growth points and the site of weather recording. In this study, the calculated thermal time was significantly different between sowing date treatments for GS of both fodder beet and sugar beet. It is possible that this may be explained by other limitations to growth that were not measured, soil moisture being one example, or by some difference in temperature being measured in a standard 1.5 m weather station rather than at ground level. However, some degree of non-linearity in the relationship between plant development and temperature cannot be excluded in this study.

These results showing increased plant populations with later sowing may also point to an associated benefit in crop production cost that has not been reported in New Zealand. The combination of greater population and faster leaf growth in later sowings would generally, although not automatically (Milford *et al*., 1985; Hussain and Field, 1991), suggest a shorter time to canopy closure in the New Zealand environment. This was not measured in this study, but if this was the effect, one consequence of the later sowing would be to alter herbicide application strategies, as faster canopy closure can substantially reduce application numbers under the current approach to herbicide application to beet crops common in New Zealand. Further study of the effect of sowing date in beet crops should include measurement of the leaf area index, which extends beyond the population to include leaf count, size and longevity, all of which may be affected by sowing date (Stephan *et al*., 2015).

It is also necessary to note that some caution need to be taken when extrapolating to New Zealand the effects of sowing date as reported for both continental Europe and Britain. Both these regions lie between 45° N and 60° N latitude, compared to New Zealand at 34° S to 47° S, and the relationship of sowing dates and plant growth stage at calendar day intervals between these therefore becomes important when extrapolating beet crop data. In addition, the use of ‘primed’ beet seed is common in these regions, and not in New Zealand. This seed, when sown earlier in cold soils, takes less time to emerge than untreated seed. Furthermore, late sown beet in Britain can be impacted by soil-borne fungus that have been reported there to cause severe losses of beet seedlings (Byford and Stamps, 1975), but not as yet in New Zealand.

Conclusions

The highest plant population was observed in later, rather than earlier, spring sowing dates for both the fodder beet and sugar beet cultivars. Later sowing dates were also associated with reduced calendar days to advanced leaf growth stage. Although there are numerous environmental and agronomic factors beyond sowing dates that influence plant count, the results of this trial suggest some benefit in plant population from later sowing dates in Canterbury. In fodder beet, earlier sowing was associated with marked increases in vernalisation, as seen in true bolter numbers. Given plant population, even establishment and vigorous early growth to obtain canopy closure are important factors in production (crop yield) and crop cost (via herbicide applications), the optimal sowing dates for regional beet crops in New Zealand warrants further research. Further, as wind damage is a documented impact on crop population and production, growers need to carefully evaluate sowing dates using both traditional growth path understanding but also regional climate probabilities, and the cultivar used. While further research is needed to establish the relationship between sowing date and crop yields under contemporary agronomic practice in New Zealand, the results of this study provide the first regional data for contemporary New Zealand beet growers to begin building decision making models for use in selecting sowing dates in accord with the local environment.

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