Dry matter accumulation of three turnip (*Brassica campestris* L.) cultivars sown on five dates in Canterbury

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Abstract

Three cultivars of *Brassica campestris* L. (cv. Appin, York Globe, and Green Globe) were sown in the field at five dates (28 January to 25 March) during one cropping season. Sowing date had a significant effect on both maximum dry matter yield and efficiency of dry matter accumulation. Total dry matter yields ranged from 1540 g/m^2 in the 28 January sowing to 590 g/m^2 in the 25 March sowing. Crops sown on 11 and 25 February achieved canopy closure faster than those from the two March sowings. Plots sown on 25 March did not achieve canopy closure. Reduced canopy development was a result of reduced rate of leaf appearance and leaf expansion. Leaf appearance rate differed over a 53% range among sowing dates, with new leaves appearing every 2.9 days (plants sown on 11 February), 3.6 days (sown 25 February), 4.7 days (sown 11 March) and 5.6 days (sown 25 March). Comparisons among sowing dates in thermal time showed no difference (P>0.05) between rate of appearance, with one leaf appearing every 40 °C·d.

Additional key words: *forage, yield, swede*

Introduction

Forage brassica production within New Zealand occupies approximately 138,000 ha. Of this, turnips occupy 40% (56,850 ha) (Banfield and Rea, 1986). The principle use of brassica crops is for quality forage for grazing in *situ* at a time of year when production from pasture is declining (Harper and Compton, 1980). Unlike perennial forage crops, quality of turnips changes only slowly with advances in maturity (Jung *et al.*, 1986).

Large variations in yield of turnips were reported by Clark *et al.* (1996), and Sheldrick *et al.* (1981). This was positively correlated with time of sowing (P<0.001), with an increase of 41kg DM/ha/d being observed in summer turnips (Clark *et al.*, 1996). However, there is little documented evidence of the effect of delayed sowing date on the subsequent yield of forage brassicas for grazing in autumn and winter as practiced by many farmers.

Environmental variables, such as temperature, affect many plant processes and especially plant development (Slafer and Rawson, 1994). Significant responses for phenological development and leaf emergence have been reported at the cultivar (Slafer and Rawson, 1994) and genotype level (Nanda *et al.*, 1996) in cereals. Within the brassica species however, the primary variable affecting development is reported to be photoperiod (Nanda *et al.*, 1996) and there is little information on thermal time effects in New Zealand.

The objectives of the following experiment were to identify the effect of delayed sowing and harvesting dates on the level and rate of accumulation of shoot and root dry matter, and changes in the parameters of leaf production of three cultivars of forage turnip.

Materials and Methods

The experiment was conducted at Lincoln University, Canterbury (latitude 42° 38′ S), with a mean annual rainfall of 586 mm (Fleming, 1996). The experimental site is an integrated soil between Templeton silt and a Templeton stony silt loam. The area had previously been in chicory based pasture for three years prior to cultivation for this experiment. Quick test soil levels prior to sowing were: pH 5.2, P 53, K 22, S 15, Ca 6 ppm, Na 5. No fertiliser was applied prior to the experiment. Site preparation was conventional tillage after deep ploughing. Weeds were controlled with atrazine at a rate of 1000 g ai/ha prior to sowing. Chemical contamination from the sprayer resulted in burning of plants in the first sowing date (28 January) and this resulted in the exclusion of this sowing date from leaf number data. There were no problems in subsequent sowing dates.

A randomised complete block split plot factorial design was used. The five main plot treatments were sowing date (28 January, 11 February, 25 February, 11 March, 25 March) and the three subplot treatments were soft turnip (*Brassica campestris* sub species *rapifera*) cultivars of three differing maturity levels (Appin, early maturing; York Globe, medium maturing; and Green Globe, late maturing). There were four replicates.

Germination tests were conducted on each cultivar under guidelines set by the Association of Official Seed Analysts (AOSA, 1990), and the sowing rate adjusted to an optimum population of 50 plants per square meter as established by Brown (1996).

Diazinon at 1600 g ai/ha was applied to plots sown on 28 January for the control of spring tails (*Collembola*) and cereal aphids (*Aphis gossypii*). Dimethoate was incorporated with seed at later sowings (11 February-25 March) at 400 g ai/ha to gain protection from springtails (*Collembola*). The mixture of insecticide and seed was sown using a hydraulically driven Oyjord cone seeder drill in 15 cm rows. At all sowings soil moisture levels were adequate for uniform germination. Application of 50 mm of water 52 days after the final sowing ensured no soil moisture deficit. Weed infestation was controlled through hand weeding. The principle weeds were self sown stinging nettle (*Urtica urens*), and Shepherds purse (*Capsella bursa-pastoris*).

Initial dry matter (DM) harvests were made 14 days after emergence in each sowing. Subsequent DM harvests were at regular intervals of between 14 and 21 days. Dry matter harvests concluded after maximum yield had been obtained. Final harvest took place 205 days after the first sowing. Harvesting involved destructive sampling of three 0.1 m^2 quadrats per subplot. Samples were washed and dissected into individual components of green leaf (including stem and leaves) and root. Samples were then washed and oven dried at 75°C to a constant weight.

The percent light transmission through the canopy (transmissivity) and leaf area index (LAI) were measured at approximately two weekly intervals using a LiCor LAI 2000 canopy analyser. Critical leaf area index, which is defined as that LAI at which 95% of incident radiation is intercepted, was also measured.

Daily radiation from a nearby (Broadfields) meteorological station was used to determine total photosynthetically active radiation (PAR). Intercepted PAR was calculated at 0.5 times the total intercepted radiation.

Soil temperature probes were placed randomly in one plot directly after the first sowing at a depth of 0 cm and 5 cm. Soil temperature was recorded every minute, averaged for every hour and day and then averaged for periods of 5 days. Further meteorological data were collected for the period of the experiment from the Broadfields meteorological station situated at Lincoln.

Dry matter production over time was analysed using functional growth analysis where generalised logistic or gompertz curves were fitted to the data (Ross *et al.*, 1979). The fitted curve parameters b, C and T were used to calculate the growth variates: weighted mean absolute growth rate (WMAGR), duration of growth (Dur) and maximum growth rate (Max GR) (equations 1 - 6). The form of equation used was determined by examining the parameters and choosing the curve of best fit.

Growth variates derived from gompertz curves were:

$$\text{WMAGR} = (b \times C)/4 \qquad (1)$$
$$\text{Dur} = 4/b \qquad (2)$$
$$\text{Max GR} = (b \times C)/e \qquad (3)$$

Where base e is the natural logarithm.

Growth variates derived from generalised logistic curves were:

$$\text{WMAGR} = (b \times C)/2(T+2) \qquad (4)$$
$$\text{Dur} = 2(T+2)/b \qquad (5)$$
$$\text{Max GR} = (b \times C)/(T+1)^{(T+1/T)} \qquad (6)$$

Treatment effects were analysed using ANOVA. Means were separated using least significant difference (LSD).

Results

Total dry matter production

Maximum total DM production was significantly reduced by delayed sowing after 11 February ($P<0.01$). Plants sown on 11 March produced only 55% of the total yield achieved from the earliest sowing (28 January) of 1540 g DM/m^2. Maximum dry matter production was greatest from cv. Green Globe ($P<0.05$), while that from York Globe and Green Globe did not differ (Table 1). No significant cultivar differences were observed for maximum growth rate (Max GR), which had a grand mean of 25.5 g/m^2/d (Table 1). Duration did not change with sowing date or cultivar (data not presented).

The weighted mean absolute growth rate (WMAGR, the average growth rate over the period of maximum dry matter accumulation) ranged from 10.3 to 20.7 g/m^2/d over the first four sowing dates and all three cultivar treatments. Plots sown on 28 January and 11 February

Table 1. The effect of sowing date on the maximum dry matter production (Max DM), maximum shoot and root DM, weighted mean absolute growth rate (WMAGR), and maximum growth rate (Max GR) of three cultivars of turnips (*Brassica campestris* L.) in Canterbury.

Treatments	Max DM (g/m^2)	Max shoot DM (g/m^2)	Max root DM (g/m^2)	WMAGR ($g/m^2/d$)	Max GR ($g/m^2/d$)
Sowing Date					
28 January	1540.0 a[1]	1015.0	525.0 a	20.7 a	34.4 a
11 February	1381.1 a	949.1	432.0 b	19.1 a	31.4 a
25 February	1060.5 b	768.5	292.0 c	13.0 b	19.6 b
11 March	842.7 c	791.7	51 .0 d	10.3 b	16.8 b
25 March	595.2 d	589.2	6 .0 d	-	-
$LSD_{P<0.05}$	172.4	115.7	76	2.9	6.5
CV (%)	15.9	15.6	3.4	19.8	27.4
Cultivar					
Appin	1105.4b	891.3	214.1 c	15.10b	24.64
York Globe	1185.4b	410.0	775.4 a	14.97b	23.77
Green Globe	1327.3a	742.8	584.5 b	17.28a	28.187
$LSD_{P<0.05}$	127.15	157.1	102.7	1.73	ns
CV (%)	14.45	20.3	46.35	15.04	

[1] Means followed by the same letter are not significantly different at P<0.05

had the greatest WMAGR of 20.7 and 19.1 $g/m^2/d$ respectively, and these were significantly greater (P<0.05) than those of the following two sowing dates. WMAGR was significantly greater (P<0.05) for cultivar Green Globe (Table 1).

Maximum crop growth rate (Max GR) followed a similar trend to WMAGR (Table 1). Plots sown early had a significantly greater maximum growth rate than those sown later. The difference between early and late sowing was equivalent to a net loss of production of about 17 $g/m^2/d$. No interactions between cultivars and sowing date were observed for Max DM, WMAGR, DUR or Max GR.

Root yields

Maximum root dry matter differed significantly (P<0.05) within cultivar (Table 1), with cv. York Globe producing the greatest root DM yield (775 g/m^2) and cv. Appin the least (214 g/m^2). A significant interaction for maximum root DM yield occurred between sowing date and cultivars. Cv. York Globe produced the greatest root DM at all sowing dates (Fig. 1). However, reductions in maximum yield occurred with delayed sowing. These were approximately 13 g DM/m^2 in cv. York Globe for every day delay in sowing after January 28. Maximum root dry matter yield of cv. Green Globe declined by 9.6 g/m^2 for every day delay in sowing from 28 January.

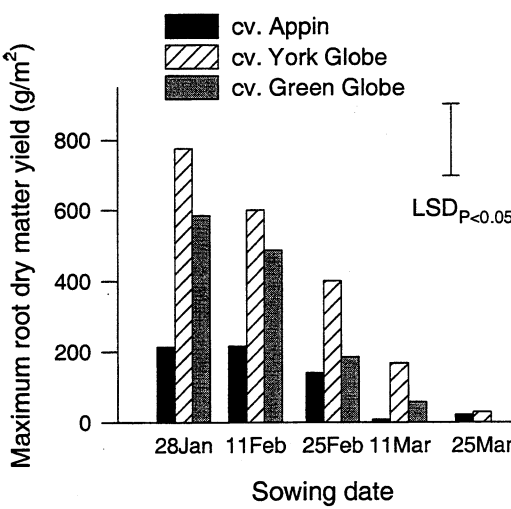

Figure 1. The effect of sowing date on maximum root dry matter yield of three cultivars of *Brassica campestris* L.

However large reductions in root dry matter of 20.1 g/m^2 occurred between plots sown on 11 March and 25 March. Cv. Appin was least affected by sowing date, with reductions of 0.33 g/m^2/d being recorded. Cv. Appin root dry matter never exceeded 216 g DM/m^2.

Shoot : Root ratio

The major contributor to total biomass production for cv. Appin was the 891 g/m^2 of top production (Table 1). The mean shoot/root quotients of cv. Appin at final harvest of plots sown on 28 January was 2.5 times that of cv. Green Globe and 6 times greater than that of cv. York Globe. Delayed sowing increased the shoot/root quotient of all cultivars (Table 2).

Significant differences in LAI were observed among cultivars. Cv. York Globe usually had the lowest leaf area (Table 3). Cv. Green Globe had a greater ($P<0.05$) LAI on 12 May compared to cv. Appin. By 30 June both cv. Green Globe and cv. Appin had a mean LAI of 3.37 compared to the 2.97 of cv. York Globe.

Biomass accumulation and radiation use efficiency

For all treatments there was a linear relationship ($P<0.01$) between accumulated total dry matter and the accumulation of intercepted PAR. Correlations of 0.99, 0.96, 0.94, 0.86, and 0.70 were calculated for plants sown on 28 January, 11 February, 25 February, 11 March and 25 March respectively (Fig. 3).

Table 2. Effect of sowing date on final harvest shoot to root ratio of three cultivars of *Brassica campestris* L.

Cultivar	28 January (134 DAS) [1]	11 February (120 DAS)	25 February (105 DAS)	11 March (92 DAS)	25 March (79 DAS)
Appin	3.0 a[2]	3.8 a	5.5 a	5.3 a	7.0 b
York Globe	0.5 a	0.8 a	1.7 b	2.5 b	4.3 b
Green Globe	1.2 a	1.9 a	5.3 a	8.6 a	13.0 a
$LSD_{P<0.05}$			3.3		
CV (%)			25.0		

[1] Number of days after sowing for final harvest
[2] For each sowing date data followed by the same letter are not significantly different at $P<0.05$, df = 30

Cv. Appin produced a higher proportion of shoot ($P<0.05$) than all other cultivars from the January 28 and February 11 sowings. All cultivars followed the same trend with cv. Appin and cv. York Globe producing 2.3 and 8.2 times the amount of shoot to root dry matter for the 25 March sowing compared with the sowing on 28 January (Table 2.). Cv. Green Globe was most responsive to delayed sowing. This cultivar had an approximate increase in shoot/root ratio of 0.2/d.

Leaf area index

Leaf canopy development was assessed using LAI. Patterns of leaf area development for successive sowings are shown in Figure 2. All plots sown from 28 January to 11 March achieved canopy closure (LAI≥ 4). Plots sown on 25 March did not acheive a closed canopy and produced a maximum LAI of 2.7. Crops sown on 11 and 25 February reached canopy closure earlier than the other sowings (at approximately 58 DAS (days after sowing) compared to 72 and 82 DAS for sowing one and four respectively). On a thermal time basis, sowing dates one to four took 1094, 871, 758 and 946 °C·d (base = 0°C) to achieve canopy closure.

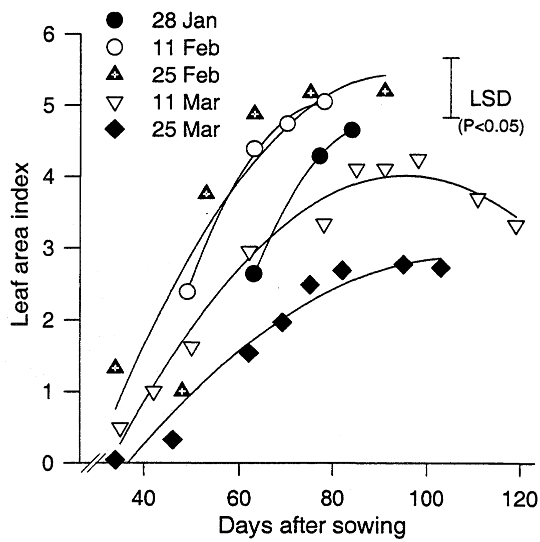

Figure 2. The accumulation of leaf area of three cultivars of *Brassica campestris* L. sown on five dates in Canterbury.

Table 3. Leaf area index of three cultivars of *Brassica campestris* L. measured at three dates in autumn/winter.

Cultivar	1 April	12 May	30 June
Appin	2.20	2.82 b[1]	3.49 a
York Globe	2.25	2.81 c	2.97 b
Green Globe	2.91	2.83 a	3.25 a
$LSD_{P<0.05}$	ns	0.01	0.32

[1] Within columns data followed by the same letter are not significantly different at P<0.05.

Plants sown on 11 February achieved a greater (P<0.05) linear response to radiation interception than that for all other sowing dates (3.29 g DM/m^2 for every MJ PAR/m^2 intercepted). The trend was for dry matter responses to reduce with delayed sowing. Plants sown on 25 March had a dry matter response of 1.60 g/m^2 for every MJ PAR/m^2 intercepted, which was less (P<0.05) than for plants from plots sown on 28 January or 11 February.

The slope of individual regression lines (Fig. 3) indicates the efficiency of conversion of intercepted radiation into biomass. Radiation use efficiency (RUE) tended to decrease with delayed sowing after 11 February.

Cv. Green Globe had the highest (P<0.05) average radiation utilisation of the cultivars over the five sowing dates (2.7 g DM/MJ intercepted PAR). However there was a significant interaction between sowing date and cultivar (Table 4). For plots sown on 28 January cv. Green Globe maintained a significantly higher (P<0.05) RUE of 3.6 g DM/MJ intercepted PAR compared to 2.2, and 2.3 g DM/MJ intercepted PAR for cvs Appin and York Globe respectively (Table 4). On the other sowing dates there were no significant differences among cultivars, although RUE ranged from 3.5 down to 1.5.

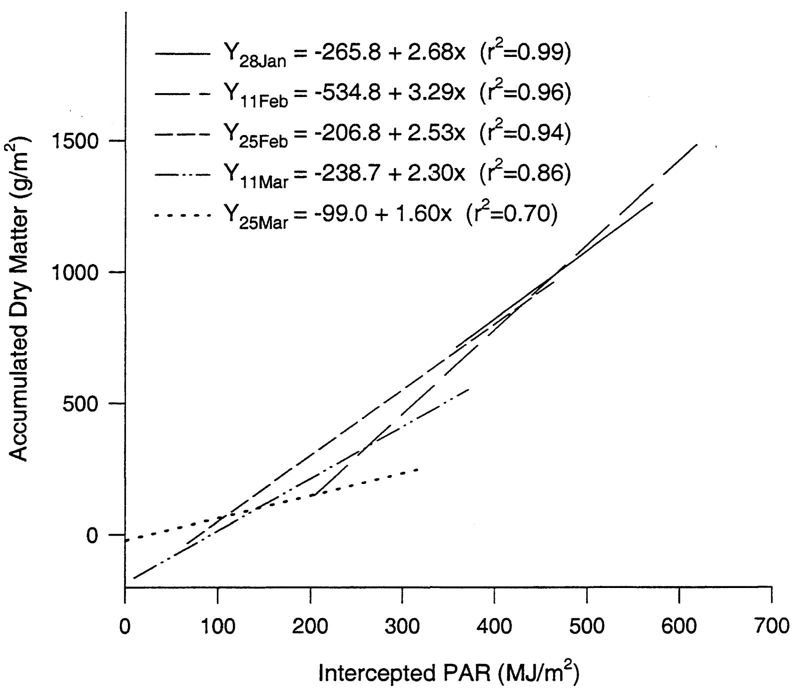

Figure 3. The relationship between cumulative photosynthetically active radiation interception and accumulated dry matter of three cultivars of *Brassica campestris* L. sown at five different dates in Canterbury.

Table 4. The interaction of sowing date and cultivar for radiation use efficiency (RUE; g DM/MJ intercepted PAR) of turnips.

Sowing date	cv. Appin	cv. York Globe	cv. Green Globe
28 January	2.2	2.3	3.6
11 February	2.8	3.4	3.5
25 February	2.1	2.6	2.7
11 March	2.5	2.0	2.2
25 March	1.6	1.4	1.5
$LSD_{P<0.05}$		0.91	

Leaf number

Total leaf number was highly correlated with days after sowing (Fig. 4). Early sowing also gave more leaves than did late sowings. Leaf appearance rates ranged from 0.346 leaves per day in the first sowing to 0.177 leaves per day in the 25 March sown plants (Fig. 4).

Cv. Appin produced leaves most rapidly ($P<0.05$) at a rate of 0.364 per day. Both cv. York Globe and Green Globe produced leaves at a slower rate of 0.185 leaves per day when data were averaged over all sowing dates. There were no interactions between sowing date and cultivar for leaf numbers.

Regression of leaf number against thermal time showed there was no difference in the rate of leaf initiation among sowing dates (Fig. 5). The mean rate of leaf initiation was 0.025 leaves per °C·d (or 40 °C·d/leaf). Cv. Appin had the fastest ($P<0.05$) leaf initiation rate, producing 1 leaf every 26.3 °C·d compared to that of 53.2 °C·d for both cv. Green Globe and York Globe respectively. Plants sown on 11 February had an appearance rate of 35.7 °C·d per leaf.. This was faster than all other sowings which had appearance rates of 43.5, 41.7, and 47.6 °C·d for plants sown on 25 February, 11 March, and 25 March respectively.

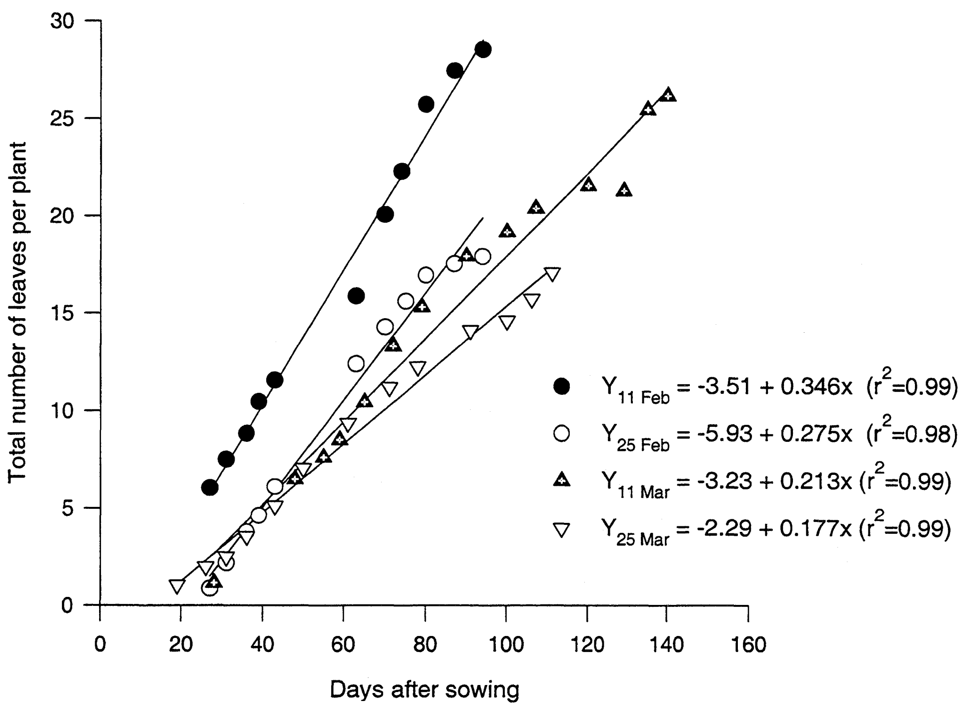

Figure 4. Plant leaf accumulation of three cultivars of *Brassica campestris* L. over four sowing dates.

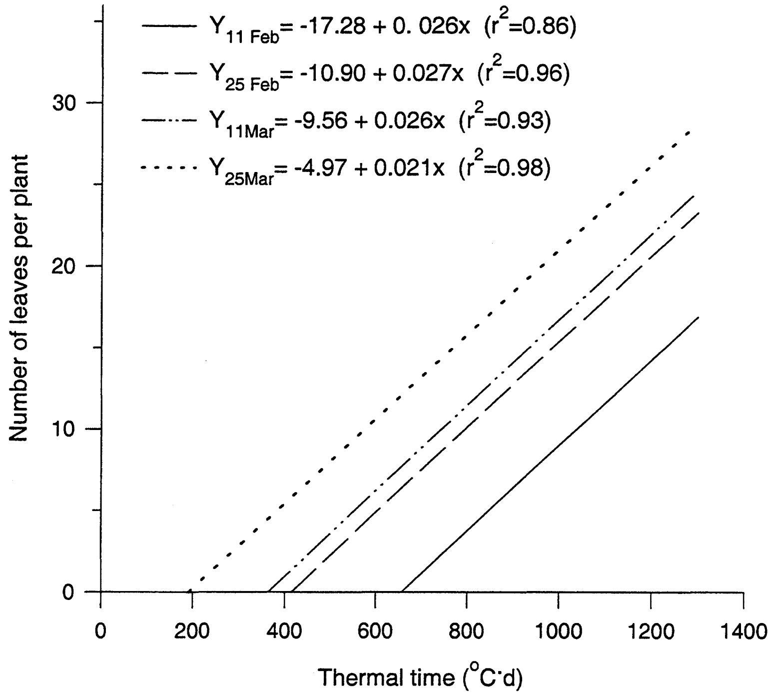

Figure 5. Relationship between total leaf number per plant and accumulated thermal time of three cultivars of *Brassica campestris* L. over four sowing dates.

Discussion

The growth of all turnip cultivars was sigmoidal. Delayed sowing decreased maximum dry matter yield, but the effect was less pronounced in early sown crops.

Crops sown on 28 January and 11 February produced nearly double the New Zealand average yield of 740 g DM/m^2 established by Clark *et al.* (1996). High early sowing yields were obtained as a result of an optimum growing season, with above average May temperatures and adequate soil moisture. Maximum growth rates (Max GR) for the first two sowings were 32.9 g/m^2/d compared to 18.2 g/m^2/d for the late sown plots. The range of DM production in this experiment (595-1540 g DM/m^2) is within the range of current commercial expectations (260-1500 g DM/m^2).

Ross *et al.* (1979), defined WMAGR as the growth rate over the period of maximum crop growth. In this study the highest growth rates occurred in the earlier sowings. These were higher than the values reported by Clark *et al.* (1996), who found an average growth rate in turnips of 12.1 g DM/m^2/d at 90 DAS from crops sown on about the 10 November. Their results were obtained from a nationwide survey of New Zealand farmers in which growth rate was calculated over the entire growth phase from sowing, whereas in this trial, WMAGR is calculated as the mean absolute growth rate over the linear phase of crop growth and therefore is greater than that reported by Clark *et al.* (1996). Variation between the trials reported by Clark *et al.* (1996) and the results described here are probably a result of the different locations and the accompanying environmental differences. Reductions of 17.0 g DM/m^2/d observed over the course of this experiment compare favourably with yield reductions of 14.0 g DM/m^2/d reported in leafy brassicas by Sheldrick *et al.* (1981) from August sowings (Northern hemisphere), as both temperatures and photoperiod are declining.

Cv. Green Globe achieved the greatest dry matter yield over all sowing dates, whereas cv. Appin stubble turnip achieved the lowest dry matter yield. These results are in general agreement with those of Harper and Compton (1980) who, using leafy forage brassica, found kale to be particularly sensitive to variation in sowing date.

Root yields of turnip consistently showed a negative response to delayed sowing, with a reduction of 20.1 $g/m^2/d$ occurring in cv. Green Globe when sowing was delayed from 11 February to 25 February. Root accumulation of cv. Appin was affected least by delayed sowing with a reduction of 0.33 $g/m^2/d$.

Delayed sowing increased the shoot/root quotient. Delays in sowing from 28 January to 25 March increased the shoot/root quotient of cv. Green Globe from 1.19 to 13.0. This was considerably greater than that for cv. York Globe and Appin which increased from 0.5 and 3.0 to 4.3 and 7.0 respectively. Later sowings of turnip therefore changed the plant structure, increasing the shoot/root quotient of the crop. This was also reported by Jung and Shaffer (1993) who found quotients as low as 7.0, which were established in early season sowings (June Northern hemisphere), increased to 13 with delayed planting.

Shoot/root quotients from early sowings (28 January and 11 February) declined during winter, due to a decline in the proportion of tops with the onset of leaf senescence, hence emphasising the storage ability of DM in the root portion of the brassica (Hook, 1981). Therefore the apparent slow decline of herbage quality in root brassicas is associated with an increasing proportion of highly digestible root DM in the total forage.

High early growth rates achieved in January and February sown plants were a result of a combination of both a long duration and high percentage of photosynthetically active radiation, resulting in greater amounts of total intercepted PAR. The monthly radiation receipts declined with delayed sowing. Therefore the total level of PAR intercepted at each sowing date decreased, supporting reports by Biscoe and Gallagher (1975) that dry matter production by crops is proportional to the total amount of radiation they intercept.

Reductions in RUE of 51% were observed between plants sown on the 11 February and those sown on the 25 March. This could have been influenced by variation in reflected PAR which was not measured but included with non-transmitted PAR. This may also be influenced by sun angle, with a lower percentage of PAR being intercepted in the late season as a result of a lower sun angle. Dry matter production was proportional to the amount of PAR intercepted, indicating the dependence on duration of radiation interception for dry matter production and the importance of time to canopy closure.

In New Zealand the annual fluctuation in incident radiation follows a broad peak, with maximum values occurring over the summer period. Therefore by sowing forage brassica under declining incident radiation, dry matter production or growth rate will decrease. This is a result of the proportion of radiation interception being dependent on the crop obtaining a critical leaf area index (LAI_{crit}) to achieve maximum PAR interception.

Canopy closure for all sowing dates ($LAI_{crit.}$) was defined as being the point where 95% of the incident PAR was intercepted. This was calculated to occur at a leaf area index (LAI) of four as Biscoe and Gallagher (1977) claimed that for most crops, when LAI reaches 4-5 more than 80% of the incident PAR will be intercepted by the canopy.

Sowing date had a dominant effect on time to $LAI_{crit.}$, with earlier sowings (11 February and 25 February) achieving LAI_{crit} at 58 DAS. Time to closure of plants sown on 28 January was slower than that of plants sown on 11 and 25 February. This was caused by herbicide damage from inadequate preparation of spraying equipment. Plants sown on 11 March required 82 DAS to achieve canopy closure and had a lower peak LAI than all earlier sowing dates. Delaying sowing until 25 March resulted in failure to achieve canopy closure, and therefore maximum radiation interception was never achieved. While thermal time to canopy closure was relatively constant, the herbicide damage influenced this, and more work is necessary to determine the relationship between thermal time and canopy closure.

The time to canopy closure for individual sowing dates was further exacerbated by declining temperatures over the autumn-winter period. This is explained by Nanda *et al.* (1995) for *B. campestris* and *B. napus,* where the upper leaves appeared faster than lower leaves at later sowing dates (December vs. October) in a Northern hemisphere environment. Therefore, the rate of progression towards canopy closure, and maximum radiation interception, is dictated by the number of leaves and rate of extension of those individual leaves (Scott and Hines, 1991).

Total leaf number varied, with plants sown on 11 February and 16 March accumulating 28.5 and 26 leaves respectively, compared to that of plants sown on 25 March which produced the fewest leaves. Early sown plants produced more leaves than late sown plants. Plants from 28 January and 11 February initiated leaves at a rate of 0.35 leaves per day, compared with rates of 0.18 leaves per day for 25 March sown crops.

Provided that the growth is not limited by severe water or nutrient stress, temperature has been shown to be the factor most controlling leaf appearance (Hay and Walker, 1989). Using thermal time the mean appearance rate for all five sowing dates was 0.025 leaves/°C·d or 40 °C·d/leaf. This suggests that temperature was the main environmental influence affecting leaf appearance. A reduced number of leaves and reduced leaf size will result in a lower LAI (assuming leaf area duration is not longer) which may reduce radiation interception and yield.

Additional work is needed on turnips to determine: the effects of temperature on leaf expansion; and to more accurately measure the thermal time needed to reach critical LAI.

Conclusions

- The optimum sowing time for irrigated forage turnip in Canterbury was from late January to mid February, when an average yield of 1460 g DM/m^2 was obtained. Delaying sowing after this time reduced yield by approximately 17 g DM m^2/d.
- Cv. Green Globe produced 14% more dry matter than both cv. York Globe and Appin.
- Dry matter production was related to interception of PAR, with 2.5 g DM being produced for each MJ of intercepted PAR.
- Leaf appearance and expansion were explained by thermal time, with one leaf appearing every 40 °C·d.

References

AOSA, 1990. Rules for Testing Seeds. Association of Official Seed Analysts, Fort Collins, Colorado, 1-109.

Banfield, R.A. and Rea, M.B. 1986. A comparison of six cultivars of forage rape over a range of sowing dates in Canterbury. *Proceedings Agronomy Society of New Zealand **16***, 49-53.

Biscoe, P.V. and Gallagher, J.N. 1977. Weather, dry matter production and yield. *In* Environmental Effects on Crop Physiology (eds., J.J. Landsberg and C.V. Cutting), pp 75-100. Academic Press, London.

Brown, G.D. 1996. The effect of seed size, sowing depth and plant population on turnip establishment and yield. Unpublished BAgrSc (Hons.) Dissertation, Lincoln University, New Zealand.

Clark, D.A. 1995. Summer milk - pasture and crops. *Ruakura Farmers Conference 1995 Proceedings*, 10-16.

Clark, D.A., Howse, S.W., Johnson, R.J., Pearson, A., Penno, J.W. and Thomson, N.A. 1996. Turnips for summer milk production. *Proceedings of the New Zealand Grassland Association **57***, 145-150.

Fleming, P. 1996. Farm Technical Manual. Department of Horticultural Management, Lincoln University.

Gallagher, J.N. 1979. Field studies of cereal leaf growth. *Journal of Experimental Botany, **117***, 625-636.

Harper, F. and Compton, I.J. 1980. Sowing date, harvest date and the yield of forage brassica crops. *Grass and Forage Science **35***, 147-157.

Hay, R.K.M. and Walker, A.J. 1989. An Introduction to the Physiology of Crop Yield. Longman, London. 292 pp.

Hook, P.J. 1981. Feed conservation: fodder cropping general techniques. *In* Aglink Farm Production and Practice. Ministry of Agriculture and Fisheries; Wellington. No. 42.

Jung, G.A., Byers, R.A., Panciera, M.T. and Shaffer, J.A. 1986. Forage dry matter accumulation and quality of turnip, swede, rape, chinese cabbage hybrids, and kale in eastern USA. *Agronomy Journal **78***, 245-253.

Jung, G.A. and Shaffer, J.A. 1993. Planting date and seeding rate effects on morphological development and yield of turnip. *Crop Science **33***, 1329-1334.

Nanda, R., Bhargava, S.C. and Rawson, H.M. 1995. Effect of sowing date on rates of leaf appearance, final leaf numbers and areas in *Brassica campestris, B. juncea, B. napus, and B. carintata. Field Crops Research **42***, 125-134.

Nanda, R., Bhargava, S.C., Tomar, D.P.S. and Rawson, H.M. 1996. Phenological development of *Brassica campestris, B. juncea, B. napus and B. carinata* grown in controlled environments from 14 sowing dates in the field. *Field Crops Research **46***, 93-103.

Ross, G.J.S., Jones, R.D., Kempton, R.A., Laukne, F.B., Payne, R.W., Hawkins, D. and White, R.P. 1979. MLP: Maximum Likelihood programme, revised edition. Rothamsted Experimental Station, Harpenden. *Annals of Botany **51***, 363-371.

Scott, W.R. and Hinds, S.E. 1991. Effects of grazing on grain yield of winter barley and triticale: The position of the apical dome relative to the soil surface. *New Zealand Journal of Agricultural Research **34***, 177-184.

Sheldrick, R.D., Fenlon, J.S. and Lavender, R.H. 1981. Variation in forage yield and quality of three cruciferous catch crops, grown in southern England. *Grass and Forage Science **36***, 179-187.