Establishment, growth and development of plantain and chicory under grazing

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Abstract
Pasture herbs can increase pasture production and feed quality over summer when ryegrass based pasture often constrains livestock production. The growth and development of plantain ('Ceres Tonic'), chicory ('Choice') and red clover ('Redmore') were related to thermal time during establishment. The time to first grazing, with sheep, was 8, 12, or 19 weeks from an autumn sowing. After 8 weeks there was > 30 % plant loss for all species compared with a loss of 3% and 13% at 19 weeks for plantain and chicory, respectively. Plantain and chicory required a minimum of six and seven true leaves, respectively, for sufficient root growth for plant survival after grazing. Modelling showed that plantain and chicory need to be sown before mid-March in Manawatu to be ready for their first grazing before winter. In their first year, plantain produced 17 t DM/ha and chicory 14 t DM/ha.
Keywords: *Plantago*, *Cichorium*, annual production, thermal time

Introduction
New Zealand's pastoral farming is based on the permanent pasture mix of perennial ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*). The herbage production and quality of this permanent pasture mix is often limited over the summer months, leading to feed deficits and lower animal production (Clark *et al.* 1996; Sanderson *et al.* 2003; Li & Kemp 2005). Lamb, deer and cattle growth rates and milk production have been shown to be greater on chicory than perennial ryegrass and white clover pastures during summer (Li & Kemp 2005). Lamb growth rates have been shown to be greater on plantain than perennial ryegrass during summer (Moorhead *et al*. 2002).

Growth habit, persistence and grazing effects on perennial forage herb crops, especially chicory, have been reported (e.g. Li *et al.* 1997; Labreveux *et al.* 2004), though there is little published literature on the establishment and early management of these perennial forage crops, and in particular on plantain. An understanding of the growth and development of these perennial herb forage crops over the first 12 months from establishment is essential in developing management strategies.

Autumn sowing is widely used in New Zealand pastoral systems to establish new pastures and perennial forage crops. The challenge of an autumn sowing is having the plants established and grazed before winter.

The objectives of this research were to determine the effect of timing of the first grazing on the establishment of plantain and chicory, in comparison to red clover, and to understand their growth and development during establishment so that it could be used to determine better management of these plants.

Materials and Methods
The trial site was on the Massey University Pasture and Crop Research Unit – No. 1 Dairy Farm at 34 m above sea level. The soil type is a Manawatu silt loam over sand. Soil test results were: pH 5.7, Olsen P 54 µg P/g, sulfate 3.8 µg S/g, potassium 0.30 me/100 g.

Before planting, the paddock was ploughed, power-harrowed and rolled to form a fine, even seed bed. The paddock was not sprayed with herbicide before ploughing. The plot trial was planted on 13 March 2006 with a 15-row cone seeder. The seed was sown on the soil surface then rolled directly after planting. Plantain, chicory and red clover were sown at rates of 8, 6 and 7 kg/ha, respectively, based on measured thousand seed weights to ensure the same density for each of the three species. The seed was sown into 6 by 18 m plots. No fertiliser was applied at planting or any other time during the study.

The experiment was a split-plot randomised block design with four replications, with a factorial combination of three pasture species and three times for the first grazing. The three species used were plantain (*Plantago lanceolata L.)* cultivar 'Ceres Tonic', chicory (*Cichorium intybus* L.) cultivar 'Choice', and red clover (*Trifolium pretense* L.) cultivar 'Redmore'. The three times of first grazing were 8, 12 and 19 weeks after sowing (WAS). The first grazing times were assigned as sub-plots and pasture species were the main plots. At the first grazing, treatments were grazed by Romney hoggets, but were subsequently grazed by Romney ewes with lambs at foot.

Plant density was measured pre- and post-grazing for each of the three first grazing treatments of 8, 12 and 19 WAS. The number of plants along 1 m of a drill row was

counted at three random sites in each plot. Final plant density was measured on only plantain and chicory, in March 2007, a year after establishment. Red clover measurements ceased after 26 weeks due to its poor establishment resulting in insufficient herbage mass for subsequent grazing. Percent plant loss after grazing for 1 complete year of establishment was then calculated for plantain and chicory.

Pre-grazing dry matter accumulation was measured by cutting herbage to ground level in a 0.25 m^2 quadrat in each plot. These samples were then washed, dried in an oven at 80°C and weighed. Pre-grazing dry matter accumulation in the three species was determined again at 26 WAS. From this time, pre and post-grazing dry matter accumulation of plantain and chicory were measured at approximately 2-monthly intervals up to the end of the experiment (March 2007). These data were then used to calculate herbage accumulation rate of the two species.

Plant development was monitored throughout the establishment of the three pasture species. At the development of the first fully expanded true leaf, 20 randomly selected plants of each species were destructively sampled. The samples were washed, separated into shoot and root material, dried at 80°C for 24 hours, and weighed. This procedure was repeated at the full expansion of every new leaf for the most developed of the three species up to 19 WAS. Thermal time requirement for the three pasture species to reach certain developmental stages was calculated from a 5°C base temperature. When the average temperature was below the base temperature then the average temperature was set equal to base temperature (McMaster & Wilhelm 1997). Air temperature and other climatic data were collected from an AgResearch weather station adjacent to the experimental site.

Dry weight production and percent plant loss data were analysed using SAS for the analysis of variance. The interaction between species and time of first grazing was not significant. The effect of thermal time on plant growth and development was determined by regression analysis using SAS. These results then were used to create a model that determined the most suitable times for sowing plantain and chicory to obtain good establishment.

Results

The rainfall from March 2006 to March 2007 (1157 mm) was higher than the average in the past (1064 mm), except during the summer months of 2006/2007. In contrast, the total sunshine hours were higher in the past (1964 h) than during the experimental period (1844 h), especially during spring and summer months. In 2006, air and soil temperatures were typical for the autumn and spring months. However, the respective minimum air temperatures were 2.7°C and 1.2°C lower in June and August. The 10 cm soil temperature was lower in June than the average. Apart from these differences, the weather at the site was typical for the autumn and winter months.

Plantain productivity before each first grazing time was always significantly higher than for the other two species (Table 1). Dry weight production of chicory at the first grazing times of 8 and 12 WAS was significantly lower than for the other two species. Before grazing at 19 WAS, dry weight production of chicory was similar to that of red clover and lower than that of plantain. Dry weight production in all species significantly increased with the delay in the first grazing time.

Grazing for the first time at 8 WAS resulted in a very high plant loss with the highest being in red clover at

Table 1 Dry weight production (kg/ha) of plantain, chicory and red clover just before first grazing times at 8, 12 and 19 weeks after sowing.

Species	Dry weight production (kg/ha)			SEM
	8 weeks	12 weeks	19 weeks	Grazing time
Plantain	849	2606	5216	
Chicory	280	1465	3026	158.5
Red Clover	436	2049	2936	
SEM Species		152.0		

Table 2 Percentage plant loss in plantain, chicory and red clover as a result of first grazing at 8, 12 and 19 weeks after sowing.

Species	% plant loss			SEM
	8 weeks	12 weeks	19 weeks	Grazing time
Plantain	37.2	13.8	3.0	
Chicory	31.5	16.1	12.9	3.93
Red Clover	49.6	48.9	21.0	
SEM Species		3.85		

Figure 1 Relationship between number of leaves/plant and thermal time (TT) of three pasture species (plantain — ◆ — Y= 8.70/1 + exp -0.014 (TT – 554.19), R^2= 0.98; chicory — ■ — Y= 6.95/1 + exp -0.014 (TT – 474.45), R^2= 0.97; and red clover —▲— Y= -0.3 exp $^{0.0028\,TT}$, R^2= 0.99).

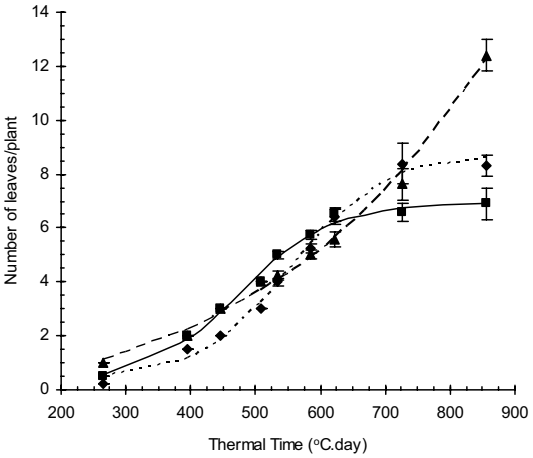


Figure 2 Relationship between plant dry weight (g/plant) and thermal time (TT) of three pasture species (plantain — ◆ — Y= 2.04/1 + exp -0.015 (TT - 678.9), chicory — ■ — Y= -0.122 exp$^{0.0054\,TT}$, and red clover —▲— Y= -0.0018 exp $^{0.0064\,TT}$) during establishment.

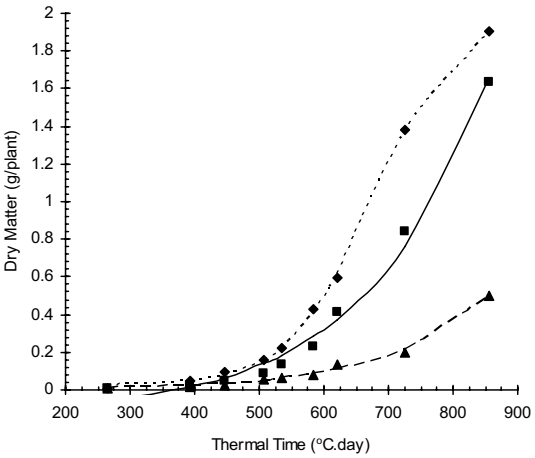


Figure 3 Herbage accumulation rate of plantain (grey) and chicory (white) for periods from March 2006 to March 2007. Bars show standard error of means.

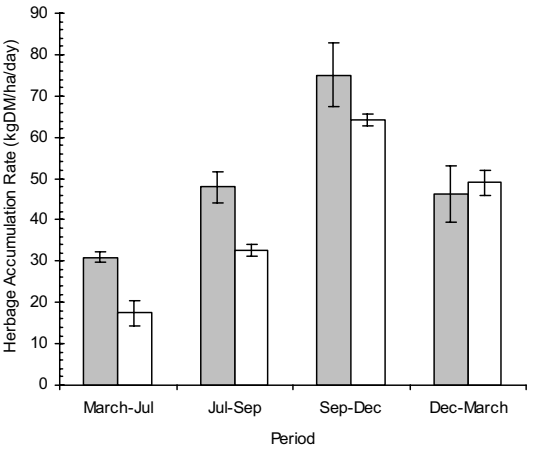
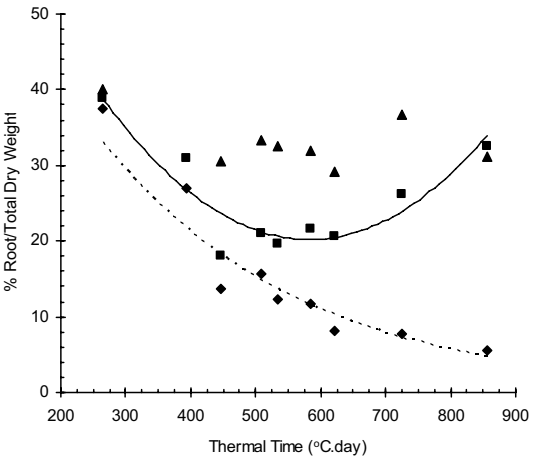


Figure 4 Relationship between percent root to total dry weight and thermal time (TT) of three pasture species (plantain — ◆ — Y= 79.15 exp $^{-0.0033X}$, R^2= 0.92; chicory — ■ — Y= 0.0002X^2 – 0.215 + 82.75, R^2= 0.85; ▲= red clover).



approximately 50% (Table 2). Delaying the first time of grazing to 12 WAS improved plant establishment significantly and plant loss at this grazing time was almost half of that at 8 WAS, except for red clover. Further delay of the first grazing time to 19 WAS improved the establishment of plantain more than it did for either chicory or red clover.

After 1 year of establishment with seven times of grazing, plantain showed better persistence than chicory. The plant density after 1 year was 67 ± 8.3 and 40 ± 2.0 plants/m^2 for plantain and chicory, respectively.

The number of fully developed leaves in plantain and chicory increased with thermal time following a normal growth curve pattern while in red clover the number of leaves increased exponentially (Fig. 1). At the beginning, chicory produced more leaves per unit thermal time compared to plantain and red clover. However, plantain produced more leaves than chicory after about 600 °C.day

of thermal time. At the final measurement, red clover had the highest number of leaves followed by plantain and chicory, respectively (Fig. 1).

Plant dry weight of chicory and red clover increased exponentially with thermal time (Fig. 2). Plantain dry weight was always higher than for the other two species and the greatest difference occurred at thermal time 726 °C.day, when plantain dry weight was 64% and 590% higher than chicory and red clover, respectively. At the final measurement time (thermal time of 855 °C.day), plantain dry weight was 16% and 280% higher than for chicory and red clover, respectively (Fig. 2). Herbage accumulation rate in plantain was always significantly higher than in chicory, except during the summer period at the end of the year (Fig. 3). Both herb species showed an increased herbage accumulation rate up to the spring months of 2006 and a decreased rate during the summer months of 2006/2007. Total dry matter production in the year for plantain (16972 ± 749.5 kg/ha) was greater than for chicory (13743 ± 752.6 kg/ha).

Percent root dry weight to total dry weight in plantain was always lower than in chicory and red clover (Fig. 4). Plantain allocated less biomass into the root than the shoot as it grew, resulting in the root to shoot dry weight decreasing exponentially with the increase in thermal time. Up to about 500 °C.day of thermal time, chicory showed the same pattern of allocation into the roots as plantain, but after 600 °C.day more biomass was allocated into the roots creating a hyperbolic pattern for percent root to total dry weight against thermal time. There was no clear pattern of percent root dry weight to total dry weight against thermal time for red clover, but its percent allocation to roots was greater than for chicory and plantain (Fig. 4).

Discussion

Both plantain and chicory showed that they were as productive as ryegrass and white clover pasture over a year and the density of both was still greater than the minimum needed for maximum herbage production (Li & Kemp 2005). The herbage accumulation rate of plantain was greater than that of chicory except in summer. Establishment of red clover was too poor to continue with herbage mass measurements beyond the grazing at 19 weeks after sowing.

Plantain and chicory display a very similar pattern of leaf development (Fig. 1) as also shown by Sanderson & Elwinger (2000). They also found that the development of leaves from autumn sowings was slower than from spring sowings. Leaf development pattern of red clover differs from plantain and chicory (Fig. 1). The difference was most likely due to the early branching of the red clover plants that increased the number of leaves per plant. Plantain and chicory plants were only just starting to produce extra shoots towards the end of the sampling period. As chicory plants age they produce multi-headed crowns with up to six shoots (Kemp *et al.* 2002), but this occurs after the first winter for autumn sown plants.

The rate of plant dry weight accumulation for plantain slowed before that of chicory and red clover (Fig. 2). This slowing in growth after 725 °C.day was possibly due to the greater early production by plantain resulting in earlier competition between plants. Alternatively, it could have been because plantain was in transition to the reproductive stage as seed heads were observed in plantain on 13 September 2006.

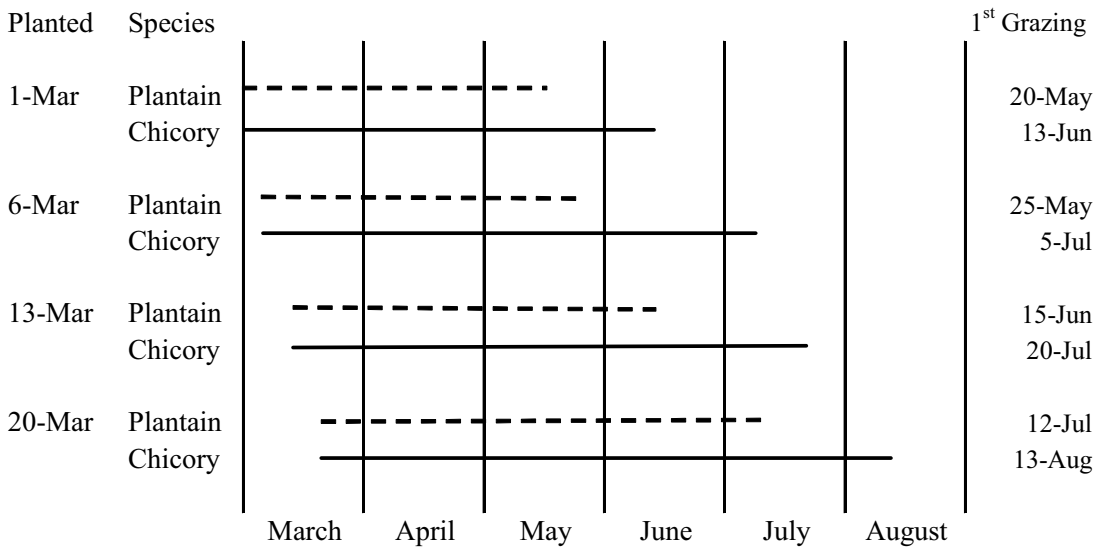
The increased percent allocation to root biomass by chicory after 500 °C.day contrasted with the continued decrease in allocation to root biomass by plantain. Sanderson & Elwinger (2000) also showed that chicory accumulated more root mass than plantain during development. More biomass allocation into the roots of chicory resulted in lower herbage accumulation rates compared to plantain during establishment (Table 1 and Fig. 4). Red clover shoot growth was also initially very slow due to the high allocation to root growth.

Delaying the first grazing time to 12 WAS, or approximately 690 °C.day of thermal time, improved persistence of plantain. However, the loss of 14% of plants is considered moderately high and plant loss of less than 10% is preferable. Based on the dry matter accumulation graph (Fig. 2), percent root to total dry matter graph (. 4) and percent loss of plant (Table 2), it is predicted that plant loss of less than 10% probably occurs when the first grazing is after 725 °C.day of thermal time (14 WAS). If that is the case, then plantain needs a minimum of six fully developed leaves, and a percentage of root dry matter to total dry matter of less than 10%, before it is ready for its first grazing. Plantain height at the six fully developed leaves stage was approximately 30 cm. Dry matter production of plantain at this stage is approximately 3 t/ha (based on prediction from Table 1).

Chicory requires more thermal time before first grazing than plantain. At 12 WAS, or even at 14 WAS, chicory was still developing the leaves needed to produce the carbohydrate to support root development. Considering results in Tables 1 and 2, chicory is ready for first grazing at 19 WAS, or at 840 °C.day of thermal time. At this stage chicory has seven fully developed leaves (Fig. 1). Chicory plant height at 19 WAS was a mean of 25 cm.

Based on the above results and discussion, a simple establishment model was generated to predict the most suitable time to sow plantain and chicory. The model predicted (Fig. 5) that sowing plantain and chicory 7 days earlier (6/3/06) than the sowing time used in this experiment (13/3/06) would result in the first grazing being 21 days earlier for plantain (25/5/06) and 15 days earlier for chicory (5/7/06). If these species are sown 1

Figure 5 Modelled sowing and first grazing dates for plantain and chicory based on thermal time requirements and weather data from 2006 in Palmerston North.



week later, on 20 March, then plantain would not be ready for first grazing until 12 July (+27 days) and chicory not until 13 August (+24 days). Later sowing than 20 March will further delay the first grazing time to early spring for chicory. Sowing earlier than the first week of March is risky since rainfall in February (mean 67 mm) is too low for seedling growth. Therefore, grazing of plantain and chicory before winter requires them to be sown in early March, with the latest time the second week of March in Manawatu conditions.

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REFERENCES

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

Kemp, P.D.; Matthew, C.; Lucas, R..; 2002. Pasture species and cultivars. pp. 83-99. *In*: New Zealand Pasture and Crop Science. Eds. White J.G.H.; Hodgson, J. Melbourne, Oxford University Press.

Labreveux, M.; Hall, M.H.; Sanderson, M.A. 2004. Productivity of chicory and plantain cultivars under grazing. *Agronomy Journal 96*: 710-716.

Li, G.; Kemp, P.D. 2005. Forage chicory (*Cichorium intybus* L.): A review of its agronomy and animal production. *Advances in Agronomy 88*: 187-222.

Li, G.; Kemp, P.D.; Hodgson, J. 1997. Herbage production and persistence of Puna chciroy (*Cichorium intybus* L.) under grazing management over 4 years. *New Zealand Journal of Agricultural Research 40*: 51-56.

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

Moorhead, A.J.E.; Judson, H.G.; Stewart, AV. 2002. Liveweight gain of lambs grazing 'Ceres Tonic' plantain (*Planatago lanceolata*) or perennial ryegrass (*Lolium perenne*). *Proceedings of the New Zealand Society of Animal Production 62*: 171-173.

Sanderson, M.A.; Elwinger, G.F. 2000. Seedling development of chicory and plantain. *Agronomy Journal 92*: 69-74.

Sanderson, M.A.; Labreveux, M.; Hall, M.H.; Elwinger, G.F. 2003. Nutritive value of chicory and English plantain forage. *Crop Science 43*: 1797-1804.