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# Sowing date affected shoot and root biomass accumulation of lucerne during establishment and subsequent regrowth season

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ABSTRACT

The pattern of perennial dry matter (DM) was manipulated over two seasons to determine if the establishment of lucerne (*Medicago sativa* L.) is regulated by the demand for assimilate by perennial organs, (taproot plus crown) or crop ontogeny. Crops of 'Stamina 5' lucerne were established from spring to late summer at two sites which differed by 230 mm to 2.3 m soil depth in plant available water content (PAWC) at Lincoln University, New Zealand. The establishment phase was characterised from sowing until crops reached a maximum accumulation of perennial biomass of ~5 t DM ha$^{-1}$. Demand for biomass offered insight into the variability in fractional partitioning of DM to the perennial organs ($P_{root}$) during establishment. This showed that $P_{root}$ was 0.48 until a perennial biomass of 2.9 ± 0.28 t DM ha$^{-1}$. Lucerne continued to partition DM to the perennial organs until a maximum biomass of ~5 t DM ha$^{-1}$, but at a decreasing rate shown by a linear decline in $P_{root}$ in response to increasing perennial biomass. This meant $P_{root}$ was independent of crop ontogeny, but most likely still under the control of environmental influences, and the establishment phase extended into the second season for crops which had not attained a perennial biomass >3 t DM ha$^{-1}$. These crops continued to prioritise the allocation of DM to the perennial organs which explained the 20–25% decrease in shoot yield in the second season when sowing was delayed. This study quantified the establishment phase of lucerne to perennial biomass demand as independent of crop ontogeny. It showed establishment was regulated by biomass demand of these perennial organs. The spring sown crops on the High PAWC soils completed this phase at the earliest in 4 months. In contrast, autumn sown crops on the Low PAWC soils took nearly 9 months to complete this phase. These results indicate different management strategies may be required to establish lucerne rather than solely using first flowering as a sign that the establishment phase is complete. Results can be incorporated into the current partitioning framework to improve the simulation modelling of lucerne.



## 1. Introduction

Crop ontogeny of lucerne (*Medicago sativa* L.) can be described by two distinct phases (i) seedling and (ii) regrowth. Agronomically, the seedling phase refers to the first growth cycle from sowing to first defoliation, which is recommended to occur at flowering (Moot et al., 2003). In contrast, regrowth phases are the growth cycles that occur following the initial and subsequent defoliation events. Alternatively, lucerne growth could be considered as an establishment phase (where perennial biomass is accumulated preferentially) followed by an established phase (where partitioning of biomass responds to environmental factors). It is important to understand the establishment phase to enable optimal stand management for maximum productivity and persistence (Fick et al., 1988). Furthermore, it may increase the accuracy of yield prediction of simulation models, which currently define lucerne phases in relation to crop ontogeny (Robertson et al., 2002).

The current recommendation is to delay first defoliation until open flower buds are observed (Moot et al., 2003). This allows maximum opportunity to establish reserves of carbon and nitrogen in the perennial organs which consist of the taproot plus crown (Justes et al., 2002; Khaiti and Lemaire, 1992; Thiebeau et al., 2011). These reserves are used to support lucerne regrowth and survival during winter (Teixeira et al., 2007a; Volenec et al., 1996). During the seedling phase, biomass is preferentially partitioned to the perennial organs as the development of the root system is a stronger sink for assimilates (Khaiti and Lemaire, 1992). As a consequence of reduced assimilate available to the shoot, these crops experience up to half the leaf area expansion rate of regrowth crops (Teixeira et al., 2011). Therefore, less intercepted radiation is available for growth,

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and seedling crops accumulate less shoot dry matter (Teixeira et al., 2011; Thiebeau et al., 2011). In contrast, the allocation of DM in regrowth crops is dynamic and the fractional partitioning of DM to the perennial organs ($P_{root}$) ranges from ~0.10 to 0.50 (Khaiti and Lemaire, 1992; Teixeira et al., 2008; Thiebeau et al., 2011) and seasonal variation has been described in relation to photoperiod and temperature (Teixeira et al., 2008).

In most temperate regions, lucerne can be sown from spring to early autumn. Delayed sowing reduces intercepted radiation by the crop in the establishment season and shoot yields decrease accordingly (Teixeira et al., 2011; Thiebeau et al., 2011). Time of sowing studies, where shoot yield has been reported over two years, shows that shoot yields in the second season can also be influenced by the time of sowing in the previous year (Justes et al., 2002; Moot et al., 2012; Teixeira et al., 2011; Thiebeau et al., 2011). Moot et al. (2012) reported the shoot yields of autumn sown crops were ~20% less in the first season after establishment, compared with their year 2–5 mean yield. Thiebeau et al. (2011) reported a similar yield reduction with delayed sowing from early spring to late summer, and showed this was due to preferential partitioning of DM to the perennial organs in the following spring, until a taproot biomass of 3–4 t DM $ha^{-1}$ was reached.

Our hypothesis is that the phase where DM is preferentially partitioned to the perennial organs is not limited only to the seedling phase. Instead crop establishment may extend further in response to the sink demand of the perennial organs for assimilates. The aims of this study were to (i) determine the length of lucerne establishment when DM allocation to the perennial organs is prioritised, and (ii) to identify if this phase is regulated by biomass demand or crop ontogeny. To do this, lucerne was sown in the field on 10 dates from spring to late summer over two years. Shoot yield and taproot plus crown biomass were quantified for the seedling and subsequent regrowth crops. To uncouple the influence of seedling phenology from DM assimilation and partitioning, growth rates were further manipulated by sowing into soils with contrasting amounts of plant available water.

## 2. Materials and methods

### 2.1. Experimental design, treatments and establishment

Dryland lucerne was established as a split-plot within a randomised complete block design, replicated four times. Sowing date was the main plot and rhizobia inoculation carrier the sub plots (4.2 × 7 m). The experiment was replicated at two sites (Lincoln University main campus and Ashley Dene Research Farm) at the same latitude, but with two distinct soil types (high and low plant available water capacity). In the first growing season (2010/2011), lucerne was sown at monthly intervals on five dates from October to February, and this was repeated in the second year (Table 1). There were four carriers of rhizobia, *Sinorhizobium meliloti* (i) lime coated, (ii) peat, (iii) ALOSCA and (iv) bare seed control. The results of that experiment have been reported elsewhere (Khumalo et al., 2012; Wigley et al., 2012).

Lime coated seed sub plots were sown in both years and are the focus of this study. Lime coated seed contains rhizobia (*S. meliloti*) and fungicide, which protect against *Pythium* spp. with additional molybdenum and lime. Prior to the first sowing date, both experimental areas were conventionally cultivated (plough, maxi-til, harrow and roll) and 'Stamina 5' lucerne seed was sown at a rate of 10.5 kg $ha^{-1}$ (bare seed equivalent) with 92% germination using an Øyjord cone seeder. All crops established >200 plants $m^{-2}$ within one month after sowing. Sequential sowing date treatments created crops which differed in perennial biomass at the end of the first year, while the second season sowing enabled a comparison of seedling and regrowth lucerne in the same year.

**Table 1**
Sowing dates for lucerne sown into soils of high and low plant available water capacity (PAWC) at Lincoln University, Canterbury, New Zealand.

| Season | Sowing date number | High PAWC | Low PAWC |
|---|---|---|---|
| 2010/2011 | 1 | 4 October | 21 October |
| | 2 | 4 November | 9 November |
| | 3 | 2 December | 8 December |
| | 4 | 10 January | 13 January |
| | 5 | 7 February | 3 February |
| 2011/2012 | 6 | 10 October | 10 October |
| | 7 | 7 November | 7 November |
| | 8 | 9 December | 9 December |
| | 9 | 10 January | 10 January |
| | 10 | 17 February | 17 February |

### 2.2. Site characteristics and meteorological conditions

The first site was at the Lincoln University main campus, located in paddock 12 of Iversen fields (43°38′S, 172°28′E, and is 11 m.a.s.l). The soil is classified as a Wakanui silt loam (*Udic Ustochrept*, USDA Soil Taxonomy), (Cox, 1978), which generally has 2–3 m of fine textured silt loam overlying gravels (Webb, 2003). The Ashley Dene Research Farm site was located in paddock M2B (43°38′S, 172°19′E, and is 30 m.a.s.l). The soil is a Lismore stony silt loam (*Udic Haplustept* loamy skeletal, USDA Soil Taxonomy), (Cox, 1978), which has a shallow topsoil (~0.2 m) that contains ~10% stones by volume, overlaying coarse gravels with a stone content up to 45% (Di and Cameron, 2002; Webb, 2003).

Meteorological data were recorded at Broadfields Meteorological Station (NIWA, National Institute of Water and Atmosphere Research, New Zealand), 2 km north of the High PAWC site. Rainfall and air temperature were recorded at the experimental sites. Mean monthly temperature was consistent between sites and ranged from 6 °C in July to 17 °C in January. Mean monthly total solar radiation ranged from 4 to 22 MJ $m^{-2}$ $day^{-1}$ over the same period. Long term mean (50 year) annual rainfall is 630 mm, distributed evenly throughout the year, but ranged from 580 mm at the Low PAWC site to 645 mm at the High PAWC site in 2011/2012. In 2010/2011, rainfall was 610 mm at both sites. Long term mean annual Penman potential evapotranspiration (EP) is 1095 mm. Monthly total EP ranges from 35 mm in June/July to 150 mm in December/January and usually exceeds rainfall from September to April. Annual EP was 975 mm and 910 mm in 2010/2011 and 2011/2012, respectively. Photoperiod was calculated by time of year and site latitude and included civil twilight (Goodspeed, 1975). Photoperiod at this latitude ranges from 10.0 h on 21 June to 16.7 h on 22 December.

### 2.3. Agronomic management

#### 2.3.1. Crop management

Soil fertility was maintained to optimum levels (Morton and Roberts, 1999) through annual chemical analysis of the topsoil (0–150 mm), each autumn and applications of superphosphate (9% P, 11% S) and potassic sulphur super (8% P, 5% K, 10% S) as required (Sim, 2014). Plots were kept weed free by chemical control and hand weeding.

#### 2.3.2. Defoliation

Seedling lucerne, defined as the growth phase from sowing to first defoliation was cut when 50% of 10 marked stems per plot had an open flower (Section 2.4.3). During the autumn months, seedling lucerne was defoliated when 50% of the marked stems had a visible flower bud as the onset of frosts meant further reproductive devel-