

# Spring growth of lucerne (*Medicago sativa* L.) after different winter grazing regimes

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## Abstract

This experiment determined if the removal of basal buds by grazing in autumn/winter affected the timing and amount of lucerne spring growth and development. The experiment was established at Iversen Field Lincoln University, New Zealand, and ran from the 1<sup>st</sup> of June 2024 to 1<sup>st</sup> of October 2024 (122 d). Grazing occurred on four dates (1<sup>st</sup> of June, 3<sup>rd</sup> of July, 17<sup>th</sup> of July, or the 1<sup>st</sup> of August) by mob stocking mixed age Coopworth ewes to simulate a “hard clean-up” winter graze. The start of rapid stem extension in spring occurred at a photoperiod of 10.8 ( $\pm$  0.2) hours for all treatments. However, shoot biomass differed at each harvest until the 3<sup>rd</sup> of September. Taproot yield at the final harvest on the 1<sup>st</sup> of October was highest in crops grazed on the 1<sup>st</sup> of June (3300 $\pm$ 124 kg DM/ha) and lowest (1100 $\pm$ 124) kg DM/ha) from those grazed the latest on 1<sup>st</sup> of August. Spring shoot biomass production was unaffected by winter grazing date. However, the ~1000 kg DM/ha lower root yield for lucerne grazed on 1<sup>st</sup> August, meant the crop would require a longer period of autumn recovery to recharge reserves to maintain stand persistence.

**Keywords:** alfalfa, basal buds, grazing, *Medicago sativa* L., photoperiod, stem extension

## Introduction

Crop growth and development are influenced by abiotic and biotic factors. Understanding these effects have been used to challenge and inform grazing management practices of lucerne (*Medicago sativa* L.) stands (Moot et al. 2003). Lucerne growth and development can be quantified by thermal time (Tt), with the duration of some development stages modified by photoperiod (Yang et al. 2021). In New Zealand the majority of cultivars have fall dormancy ratings of 4-5 (semi-winter dormant) and show seasonal differences in remobilisation and partitioning of reserves. In autumn, this manifests as short stems that accumulate nodes at a slower rate than would occur when rapid stem expansion is triggered in spring (Moot et al. 2003). Spring growth is a critical time in rainfed (dryland) sheep systems, where the aim is to maximise lamb

liveweight gain on high quality feed (Moot et al. 2016) to enhance farm systems (Moot et al. 2024). Current lucerne grazing recommendations are to enter Paddock 1 of a six paddock rotation when the stems reach ~150 mm (Moot et al. 2016) to ensure stem heights are <400 mm when stock enter Paddock 6. This recommendation aims to maximise utilisation and provide 4-5 weeks of continuous feed. Jones et al. (2024) found that reducing the initial entry height to ~100 mm in Paddock 1 maintained stem heights below ~300 mm at Paddock 6 and this maintained utilisation at 85% in all six paddocks in the first spring rotation. In Canterbury, this corresponds to commencement of grazing by 3<sup>rd</sup> of September, before rapid stem extension occurs. A limitation to this previous study (Jones et al. 2024) is that the basal buds were not removed in the simulated “graze” process, so the impact of a hard winter grazing that did remove the basal buds was not considered.

If basal buds are removed during the winter “clean-up”, then new shoots must be initiated from the crown to become the mature stems in the first spring rotation (Langer 1968). The number of basal buds that appear after defoliation is dependent on the cultivar and environment. The shoot yield produced within each rotation is then dependent on the number of well-developed basal buds that have been initiated to take the place of shoots removed through grazing. Jones et al. (2024) reported that when the basal buds were not removed in winter, the shoot yield for the first spring rotation was not different across a range of eight “clean-up” dates. This suggested that lucerne had initiated sufficient basal buds to counteract the later defoliation dates. However, the ability of lucerne to recover after a defoliation event is dependent on the residual leaf area, and the quantity of available carbohydrate reserves (Langer and Keoghlan 1970; Teixeira et al. 2007b). In winter these reserves have to come predominantly from remobilisation because leaf area is minimal. Jones et al. (2024) cut lucerne to a residual height of ~40 mm above the crown, which left initiated buds that had previously emerged intact at the base of the sward. This suggests the surviving buds produced sufficient leaf area to support photosynthesis immediately post-cutting. However, when the basal buds are removed, the

**Table 1** Mean air temperature (°C), total rainfall (mm) and total Penman potential evapotranspiration (PET), and total solar radiation (MJ/m<sup>2</sup>) from 1 June 2024 until 31 October 2024, recorded at the Broadfields meteorological station (Agent Number 17603; <https://cliflo.niwa.co.nz/>). The long-term mean (LTM) is the mean for the period 1993 to 2023.

	Mean Air Temperature	Total Rainfall	Total Penman PET	Total Solar Radiation
Months	(°C)	(mm)	(mm)	MJ/m <sup>2</sup>
June	8.13	65.6	13.7	167
July	7.02	50.0	15.8	184
August	8.24	45.6	40.4	299
September	10.22	29.4	73.3	463
October	11.97	64.8	95.4	610
<b>Mean</b>	9.11	51.1	41.3	345
<b>LTM<sup>a</sup></b>	12.10	50.50	57.70	319

<sup>a</sup>LTM denotes a long term mean

plant must remobilise carbohydrate reserves from the taproot to initiate a new cohort of basal buds (Langer and Keoghan 1970). Defoliation events with short subsequent regrowth cycles limit canopy expansion and hence shoot growth. Basal bud production is then compromised because the assimilation of carbon and nitrogen that can be allocated and remobilised for growth is reduced (Teixeira et al. 2007b).

Based on the previous results, the aim of this experiment was to refine the winter grazing management recommendations required to enhance utilisation in the 1<sup>st</sup> spring regrowth cycle after the winter “clean-up”. To do this, the basal buds of winter grown lucerne were removed by heavy grazing at four different dates. The effect on initial spring growth and development was measured.

## Materials and Methods

The experiment was located in Iversen Field, at the Lincoln University Field Research Centre, Canterbury, New Zealand (-43.649, 172.465). The soil type is an imperfectly to moderately well-drained Wakanui silt loam (Aquic Haplustept, USDA Soil Taxonomy), which is prone to waterlogging during periods of excess rainfall (Hewitt 1998). Wakanui silt loams typically have 0.3 m of topsoil overlying silt loam dominant horizons to a depth of 3.5 m (Cox 1978). Webb (2003) reported that the plant available water-holding capacity for a Wakanui silt loam is 150 mm/m. Rainfall (mm), solar radiation (MJ/m<sup>2</sup>/d), air temperature (°C), and Penman evapotranspiration (mm) were recorded at the Broadfields meteorological station (Agent number 17603) (Table 1). This is located 2 km to the north of Lincoln University using NIWA's (National Institute of Water and Atmosphere) equipment.

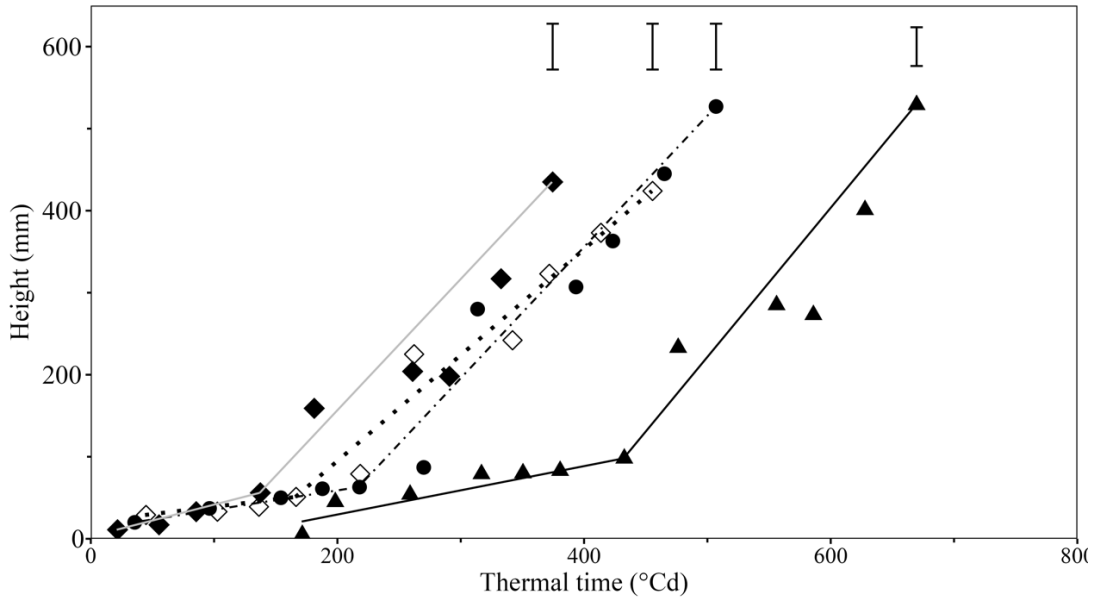
The experiment was conventionally drilled with a Flexiseeder 14 coulter plot drill on the 21<sup>st</sup> of October 2021 at a sowing rate of 12 kg/ha of inoculated ‘Force 4’

lucerne, and at a target depth of 15 mm. The experiment was a randomised complete block design with three replicates and four winter grazing dates (1<sup>st</sup> of June, 3<sup>rd</sup> of July, 17<sup>th</sup> of July, or the 1<sup>st</sup> of August) in 2024. The 10 x 20 m plots were hard grazed by 200 mixed age Coopworth ewes/ha for three days until all herbage was removed. The experiment ran for a single rotation from the date the grazing treatment was implemented, to the 1<sup>st</sup> of October 2024.

Lucerne plant height was measured weekly on five marked stems in each plot to quantify recovery from grazing. Shoot yield was measured at fortnightly intervals after grazing by cutting a 0.2 m<sup>2</sup> quadrat in each plot to crown level (~1 cm above ground level). Samples were oven dried at 65°C for at least 48 hours to a constant weight. At the final harvest (1<sup>st</sup> of October), roots within the quadrat area were dug out in a wedge to a ~300 mm depth from a 0.2 m<sup>2</sup> quadrat area. Roots were washed above a sieve as not to lose any material and dried at 65°C for at least 48 hours to a constant weight.

Thermal time was calculated from daily maximum and minimum air temperatures using a three-stage model (Moot et al. 2001). Cardinal temperatures were a base temperature of 0 °C, inflection point of 15 °C, optimum temperature of 30 °C, and maximum temperature of 40 °C. Thermal time accumulation began the day after stock were removed from each treatment. Heightchron (°Cd/mm) was calculated as the slope of height against thermal time.

Statistical analyses were carried out in R Studio 4.2.1. A one way analysis of variance was performed on height, shoot and root yield data. Broken stick regressions were used to analyse the relationships between height, thermal time and photoperiod for each plot. The regression parameters (slope, Phase 1 and Phase 2 and the break point) were compared by ANOVA. Means were separated by Fishers protected



**Figure 1** Stem height (mm) against thermal time ( $^{\circ}\text{Cd}$ ) for lucerne defoliated on four different dates, 1<sup>st</sup> of June (▲), 3<sup>rd</sup> of July (●), 17<sup>th</sup> of July (◐), or the 1<sup>st</sup> of August (◆), at Lincoln University, Canterbury New Zealand. The vertical bars are the SEM for the slope of height against thermal time.

LSD at the  $\alpha=0.05$  level. Treatment means are reported with the respective standard error of the mean. Grand means are reported where no treatment effect was observed are reported with the pooled SEM.

## Results

### Heightchron: Phase 1 – winter dormancy

Thermal time was accumulated for Phase 1 from one day after defoliation ended until the breakpoint of the broken stick regression which indicated the start of stem extension. Phase 1 differed ( $P < 0.001$ ) for all treatments (Figure 1). The earliest winter graze treatment (1<sup>st</sup> June) accumulated the most thermal time (432  $^{\circ}\text{Cd}$ ) before the start of stem extension. This was almost double the 217  $^{\circ}\text{Cd}$  accumulated for treatments grazed on the 3<sup>rd</sup> of

July and more than triple the 137  $^{\circ}\text{Cd}$  accumulated for the latest grazing treatment (1<sup>st</sup> August). Regardless of these differences the slope of the relationship between lucerne height and thermal time in Phase 1 estimated a heightchron ( $^{\circ}\text{Cd}/\text{mm}$ ) of 4.47 ( $\pm 0.31$ )  $^{\circ}\text{Cd}/\text{mm}$  which was not different ( $P = 0.44$ ) among the defoliation treatments (Table 2).

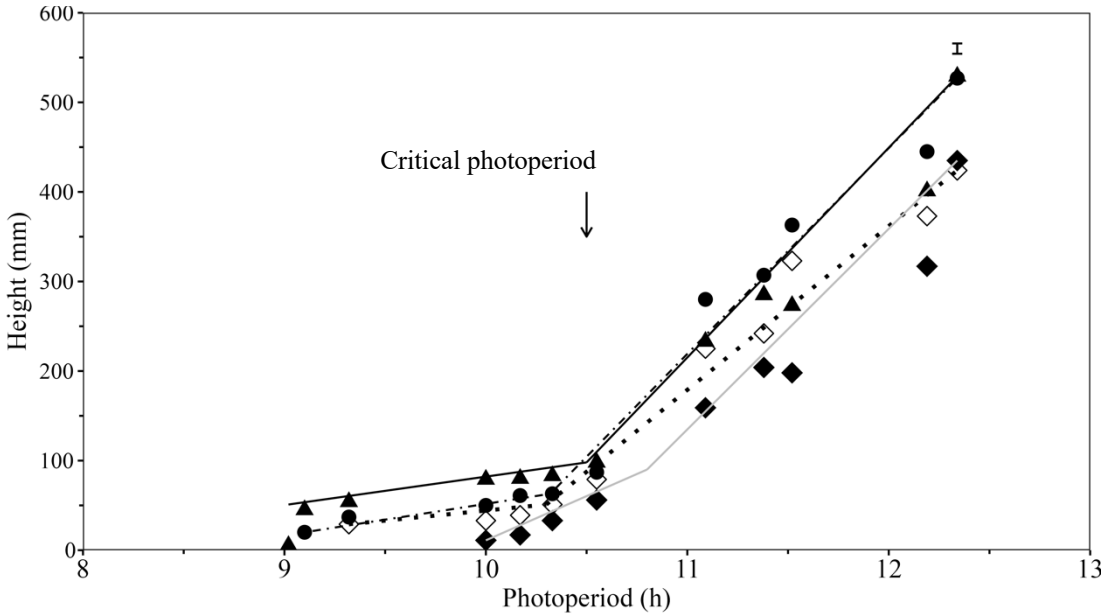
### Heightchron: Phase 2 – stem extension

The duration of Phase 2 was from the initiation of stem extension until the experiment terminated on 1<sup>st</sup> of October 2024. During this stem extension phase, defoliation treatments had a common ( $P = 0.66$ ) heightchron of 0.96 ( $\pm 0.01$ )  $^{\circ}\text{Cd}/\text{mm}$ , with no significant effect of defoliation treatment on rate.

**Table 2** Parameters from broken stick regression analyses of stem height (mm) against thermal time ( $^{\circ}\text{Cd}$ ) for lucerne defoliated on four different dates at Lincoln University, Canterbury, New Zealand. SEM is the standard error of the mean.

Defoliation date	Breakpoint ( $^{\circ}\text{Cd}$ )	Slope ( $^{\circ}\text{Cd}/\text{mm}$ )		$R^2$
		Phase 1	Phase 2	
1 <sup>st</sup> of June	432 <sub>a</sub>	5.75	0.54	0.86
3 <sup>rd</sup> of July	217 <sub>b</sub>	4.44	0.56	0.89
17 <sup>th</sup> of July	166 <sub>c</sub>	3.94	0.73	0.93
1 <sup>st</sup> of August	137 <sub>d</sub>	3.84	0.82	0.91
Mean	244	4.47	0.66	-
SEM	42.4	0.31	0.06	-
P value	<0.001	0.09	0.49	-

Note: - indicates data not analysed. Means followed by the same letter are not different at the  $\alpha=0.05$  level.



**Figure 2** Stem height (mm) against photoperiod (h) for lucerne defoliated on four different dates, 1<sup>st</sup> of June (▲), 3<sup>rd</sup> of July (●), 17<sup>th</sup> of July (▲), or the 1<sup>st</sup> of August (◇), at Lincoln University, Canterbury New Zealand. The vertical bars are the SEM for the slope of height against photoperiod.

**Table 3** Parameters from broken stick regression analyses of stem height (mm) against thermal time (°Cd) for lucerne defoliated on four different dates at Lincoln University, Canterbury, New Zealand. SEM is the standard error of the mean.

Defoliation (2024)	date	Breakpoint (h)	Date of breakpoint	Slope (mm/h)		R <sup>2</sup>
				Phase 1	Phase 2	
1 <sup>st</sup> of June		10.6	29 <sup>th</sup> August	27.0 <sub>b</sub>	132	0.85
3 <sup>rd</sup> of July		10.8	30 <sup>th</sup> August	31.4 <sub>b</sub>	224	0.89
17 <sup>th</sup> of July		10.7	29 <sup>th</sup> August	11.9 <sub>b</sub>	192	0.89
1 <sup>st</sup> of August		10.9	31 <sup>st</sup> August	56.3 <sub>a</sub>	183	0.94
Mean		10.8	30 <sup>th</sup> August	31.7	182.8	-
SEM		0.08	-	5.75	4.10	-
P value		0.12	-	0.01	0.17	-

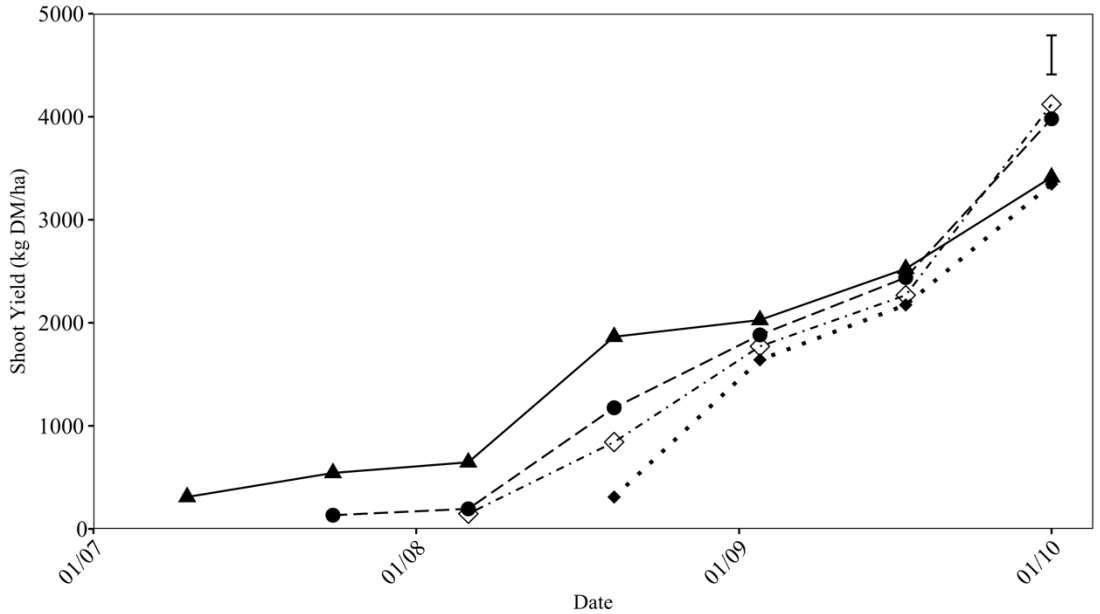
Note: - indicates data not analysed. Means followed by the same letter are different at the α=0.05 level.

**Critical photoperiod to trigger stem extension**

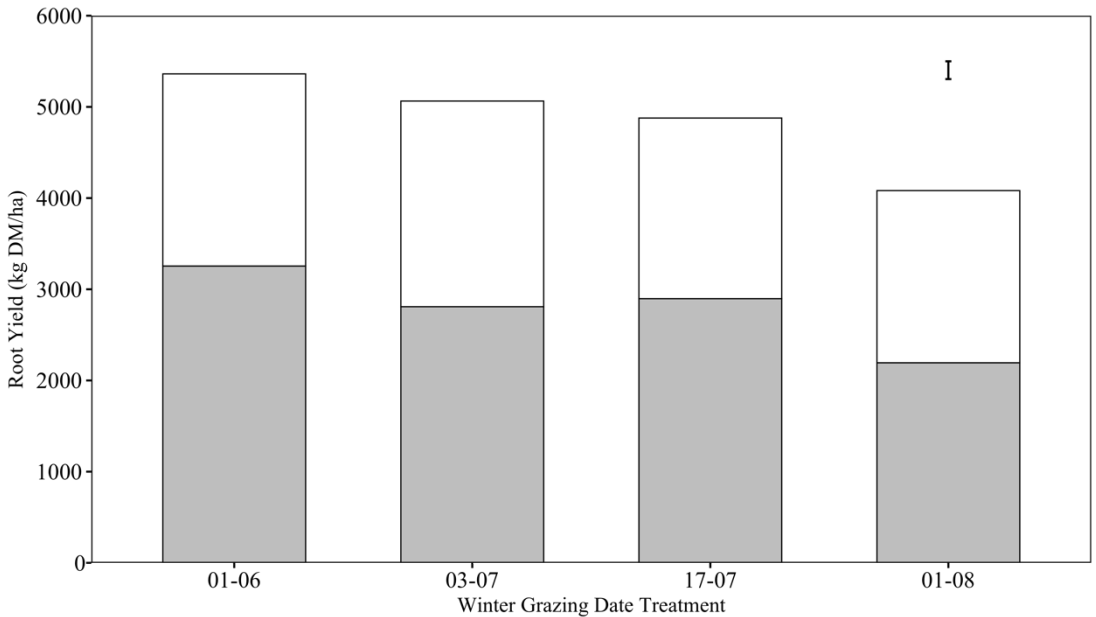
The start of rapid stem extension was not different (P = 0.12), despite winter grazing times differing by up to 61 days, and occurred at a photoperiod of 10.8 (± 0.2) hours (Figure 2), which occurs on August 30<sup>th</sup>. The slope between stem height and photoperiod during the lag phase only differed (P = 0.01) at the final sampling date (1<sup>st</sup> October) (Table 3). The slope of height against photoperiod during the stem extension phase (Table 3) was not different (P = 0.17) among defoliation dates.

Shoot yield differed (P < 0.05) at each of the sampling dates until the 3<sup>rd</sup> of September (Figure 3). At the first harvest (10<sup>th</sup> of July) only the 1<sup>st</sup> of June grazing treatment had been implemented. By the 24<sup>th</sup> of

the July the 1<sup>st</sup> of June grazing treatment had produced 540 (±97) kg DM/ha, which was 400 kg DM/ha more (P = 0.04) than was produced by lucerne grazed on the 3<sup>rd</sup> of July. On the 6<sup>th</sup> of August pastures grazed on the 1<sup>st</sup> of June had accumulated 650 kg DM/ha which was 73% more (P = 0.003) than the 3<sup>rd</sup> and 17<sup>th</sup> of July grazing treatments (170±82 kg DM/ha). By the 20<sup>th</sup> of August, the lowest yield was from the 1<sup>st</sup> of August grazing (300 kg DM/ha). This was 70% lower (P = 0.004) than the shoot yield from pastures grazed on the 3<sup>rd</sup> and the 17<sup>th</sup> of July (1000±180 kg DM/ha) and these were 45% lower than the 1800 kg DM/ha accumulated by lucerne grazed on the 1<sup>st</sup> of June. However, by the harvest on the 3<sup>rd</sup> of September, shoot yields were not



**Figure 3** Shoot yield (kg DM/ha) over time for lucerne defoliated on four different dates, 1<sup>st</sup> of June (▲), 3<sup>rd</sup> of July (●), 17<sup>th</sup> of July (◇), or the 1<sup>st</sup> of August (◆), at Lincoln University, Canterbury, New Zealand. The error bar is the SEM at the final harvest (1<sup>st</sup> October).



**Figure 4** Crown biomass (kg DM/ha) (□) and taproot biomass (kg DM/ha) (■) of four different winter defoliation treatments (1<sup>st</sup> of June, 3<sup>rd</sup> of July, 17<sup>th</sup> of July, or the 1<sup>st</sup> of August) harvested on the 1<sup>st</sup> of October 2024 at Lincoln University, Canterbury New Zealand. The error bar is the SEM for the total root yield (crown+taproot; kg DM/ha) to a depth of 300 mm.

different ( $P > 0.05$ ) among the treatments ( $1900 \pm 117$  kg DM/ha). This lack of treatment effect on accumulated shoot yields continued until the experiment ended with yields of  $2300 \pm 30$  kg DM/ha on the 17<sup>th</sup> of September, and  $3700 \pm 87$  kg DM/ha on the 1<sup>st</sup> of October.

At the final harvest, crown weight ( $2000 \pm 159$  kg DM/ha) was not different among winter graze treatments ( $P = 0.58$ ). However, taproot yield was highest from the 1<sup>st</sup> of June grazing treatment ( $P < 0.01$ ; 3300 kg DM/ha). The lowest taproot yield was from the

1<sup>st</sup> of August grazing treatment (2200 kg DM/ha). The 3<sup>rd</sup> and 17<sup>th</sup> of July treatments were not different from each other (2800±124 kg DM/ha).

## Discussion

Rapid stem extension in spring (Figure 2; Table 3) commenced at a photoperiod of 10.8 (± 0.2) hours (30<sup>th</sup> of August), despite the 61 day difference in the date that basal buds were removed. This result was comparable to the 11 (± 0.2) hour critical photoperiod reported previously by Jones et al. (2024) and Yang et al. (2021). As a consequence, the thermal time accumulated to reach stem extension differed among grazing treatments (Figure 1) and no single value could be used to predict the start of stem extension post-grazing. This supports the hypothesis that stem extension occurs at a critical photoperiod, and therefore this would be more reliable as an indicator of the start of stem extension. Shoot yield differed among defoliation date treatments until the 3<sup>rd</sup> of September (Figure 3), which corresponded to the critical 11 h photoperiod in Lincoln, Canterbury. Jones et al. (2024) previously suggested that grazing prior to the critical photoperiod would allow for staggered growth in the first spring grazing rotation. The first rotation is critical for sheep grazing systems as it is when ewes and lambs have high nutritive requirements (Moot et al. 2016), so the production of high quality feed with corresponding high utilisation is necessary to meet demand. Jones et al. (2024) also reported that shoot yield differed until the point of stem extension, but did not discuss the possible trade-offs of a late winter graze.

When lucerne is defoliated, the carbohydrate reserves required for initiation of basal buds to form new shoots must be remobilised from taproot reserves (Langer and Keogh 1970). Short defoliation periods typically produce taproot yields which were ~1000-2000 kg DM/ha lower than when plants are allowed to recharge root reserves (Teixeira et al. 2007a). This is consistent with the taproot yield for the lucerne defoliated on the 1<sup>st</sup> of August, which was 600-1100 kg DM/ha lower than all other treatments on the 1<sup>st</sup> October. In this experiment the basal buds were removed through grazing at high stocking rates to simulate a commercially recommended hard winter clean-up graze as part of on-farm management. In practice, removal of the basal buds by the sheep was difficult. It took three days at a high stocking rate because the ewes typically grazed the leaf from the taller, older stems first. Therefore, on-farm it can be expected that in most cases the clean-up graze would not remove the basal buds and thus the impact of their removal would be minimised. Retention of these basal buds and some green leaf area capable of photosynthesis can be expected to reduce the reliance

on remobilized reserves (Teixeira et al. 2007a). This can be managed in winter through lower stocking rates, or removal of sheep before basal buds are grazed.

In spring, lucerne grazing management is focussed on maximising lamb liveweight gains with a priority to get ewes with lambs grazing as soon as practicable (Moot et al. 2016). In autumn, the focus switches to longer rotations to allow for carbohydrate and nitrogen translocation to maintain stand longevity. Winter grazing as late as the 1<sup>st</sup> of August allows for greater flexibility around grazing management, but did reduce lucerne taproot yields by ~600-1100 kg DM/ha. These results suggest that after a late winter graze stand persistence could be achieved by a longer spell in the following autumn to ensure root reserves are replenished to levels comparable to the other treatments. Teixeira et al. (2007a) looked at lucerne root and shoot growth in response to different regrowth durations, including a 42 day cycle until 4<sup>th</sup> February and 28 day cycle (LS), and a 28 day cycle until 4<sup>th</sup> February and 42 day cycle during the remainder of the growth season (SL). Their LS treatment, where plants did not receive the required spelling period in autumn, produced 5000 kg DM/ha/y less lucerne shoot yield than the SL treatments that had an autumn spell the following season. The LS treatment also produced up to 2000 kg DM/ha less taproot yield than those given a longer autumn spell. Their results support the idea that grazing later in winter will not impact the longevity of the stand, as long as the stand is afforded a spelling period during late summer/autumn, under decreasing photoperiod.

The start of stem extension also did not differ from the range of 11 (± 0.2) reported previously by Jones et al. (2024) and Yang et al. (2021). This validates these functions for the prediction of stem height and shoot yield in spring at this location. Jones et al. (2024) reported that, for the first spring rotation, the optimal stand height at entry was ~100 mm for the first paddock in a six paddock rotation. This was lower than the ~150 mm previously recommended (Moot et al. 2016). The ~100 mm was deemed optimal as this was the stem height prior to the critical photoperiod, and allowed for staggered grazing entry heights through the first rotation with ewes and lambs. Here, stem height at the critical photoperiod was ~90 mm, which was slightly lower than reported by Jones et al. (2024). At the critical photoperiod, shoot yield was 1900±30 kg DM/ha (Table 3). Mills et al. (2016) reported that for every 100 mm in stem height there will be ~900 kg DM/ha. This is lower than was observed in 2024, which infers that there was more leaf material than stem. This aligns with the principles of lucerne producing nodes and leaves in winter ready for rapid stem extension in spring (Moot et al. 2003).

## Conclusions

The critical photoperiod for stem extension was 10.8 ( $\pm$  0.2) hours, irrespective of the time of the winter “clean up” grazing date, which differed by 61 days across the four treatments imposed. The value is comparable to previously published reports, giving further validation to this function. Shoot yield was not different among winter defoliation treatments after rapid stem extension was initiated. This gives farmers greater flexibility around winter grazing management, especially during periods of feed deficit, typically associated with increased animal demand in late winter/early spring. However, there is a trade-off because late winter grazing (1<sup>st</sup> of August) reduced taproot reserves. Thus, to restore taproot storage reserves for the following spring the stand will need a longer spelling period in the autumn to partition more carbohydrates below ground. Further research could look into the carbohydrate loss from the taproots, the method of loss and whether the critical photoperiod holds for FD 4-5 cultivars in different locations.

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