Main-stem node appearance of lucerne regrowth in a temperate climate

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Abstract

Irrigated crops of ‘Grasslands Kaituna’ lucerne were grown over five years in a temperate climate at Lincoln University, Canterbury, New Zealand (43?38?'S, 172?28?’E). From these the environmental responses of main-stem node appearance were determined. A broken stick temperature threshold with a base temperature (T_b) of 1?C at air temperatures (T_a) <15?C and a T_b 5?C for T_a ≥15 was required to accurately accumulate thermal time (Tt). Using this, main-stem node appearance (phyllochron) was constant in relation to Tt within a regrowth cycle (30–42 days). The phyllochron was 37????7?Cd except in declining photoperiods from 15.7–11.4 h when it decreased from 60–37?Cd. These results demonstrate one of several peculiarities of lucerne physiology in a temperate climate that need to be considered to provide a quantitative framework for lucerne crop simulation.

Media summary

Main-stem node appearance of ‘Grasslands Kaitua’ lucerne was linear in response to thermal time accumulation but the rate (phyllochron) varied in response to photoperiod.

Key words

thermal time, phyllochron, photoperiod.

Introduction

Main-stem node appearance is the central component of leaf area index expansion and subsequent radiation interception and growth (Robertson et al. 2002). Therefore quantifications of the environmental responses of node appearance are necessary for the simulation of lucerne growth. Main-stem node appearance is a development process and is generally related to Tt accumulation to estimate the phyllochron. The Tt accumulation of lucerne has usually been calculated with a base temperature of 5??C (Fick et al. 1988) but Sharratt et al. (1989) and Moot et al. (2001) have both presented results from cool climates that suggest this base temperature is too high. Robertson et al. (2002) has re-analysed some published growth cabinet data to derive a single phyllochron of 34?Cd. However, there is a lack of suitable field data to justify a single phyllochron and Moot et al. (2001) has suggested it changes throughout the season in response to photoperiod (Pp).

The objective of this study was to provide a quantitative framework to describe any environmental responses of the main-stem node appearance of a crop of ‘Kaituna’ lucerne monitored over a five-year period at Lincoln University.

Materials and Methods

General

Measurements were conducted in three replicate plots from two experiments in adjacent fields (Iversen 8 and 9) at the Lincoln University (43?38?'S, 172?28?’E). Iversen 8 was sown (7?kg ‘Grasslands Kaitua’ seed/ha) in November 1996 and observations were conducted over 5 years from July 1997 – June 2002. Iversen 9 had 4 sowing dates at three-week intervals from 24 October 2000. Observations in Iversen 9 began following the first defoliation (12 weeks after sowing) and continued for 2 years to June 2002. Irrigation was applied as necessary to maintain a soil water deficit <200?mm in the top 2?m of soil (Brown et al. 2003) for both crops. Mean daily temperature ranged from 6?C in June/July to 17?C in January/February, Pp increases from 10?h on 21?June to 16.6?h on 21 December and mean total daily radiation receipt increases from 5–23?MJ?m^{-2} over the same period.

Return counts of main-stem nodes were taken at 3–7 day intervals on 15 marked main-stems of individual plants (five per replicate). The number of main-stem nodes was counted from the base of the stem to the node with the most recently fully expanded leaf. Stems were marked within five days of the removal of sheep from the previous grazing period when they were 20–50?mm long. An intentional bias was made to mark the tallest stems at this time because smaller stems often failed to extend for the full duration of the regrowth cycle.

Analysis

The phyllochron (?Cd) was calculated from the reciprocal of the slope of a linear regression between main-stem node number and accumulated Tt within each regrowth cycle. Thermal time (?Cd) was calculated daily using the method described by Jones and Kiniry (1986) and daily Tt was summed to give accumulated Tt between successive events.

Two temperature thresholds were compared to select the most suitable for describing Tt accumulation of lucerne in a temperate climate. The first threshold (Tt_{b5}) used a linear increase in Tt from a T_b of 5?C, an optimum (T_o) of 30?C followed by a linear decrease to a maximum (T_m) of 40?C (Fick et al. 1988). An alternative threshold ($Tt_{b1/5}$), which is the same as Tt_{b5} for T_a ≥15?C but accumulates Tt at 0.71??Cd per ?C above a T_b of 1?C for T <15?C (Moot et al. 2001), was also tested. Two tests were used to compare thresholds; the first was to compare the coefficient of variation (CV, %) for phyllochrons calculated from each threshold. The second test was a regression of phyllochron as a function of mean observation period temperature to check for systematic errors.

Phyllochrons calculated from the selected Tt threshold were plotted as a function of Pp on the day of first node appearance to quantify the Pp response of node appearance.

Results

Temperature threshold

The phyllochron calculated with Tt accumulated with the Tt_{b5} threshold had a CV of 25% and a slope of 0.84 indicating an underestimation of Tt at lower temperatures. In contrast, the $Tt_{b1/5}$ temperature threshold had a lower CV of 22% and a slope of zero. This indicates no systematic error over the observed mean temperature range (7.5–18?C) so the $Tt_{b1/5}$ threshold was used to calculate Tt.

Main-stem node appearance in response to thermal time

Main-stem node appearance was linear within regrowth crops (Figure 1) with R^2 > 0.9 in all situations indicating the phyllochron was constant within each regrowth cycle. However, there was a decrease in the slope of regressions in the latter part of each growth season. Some points at the end of regrowth cycles were excluded from regressions because node appearance became non-linear when lucerne started to flower or after a frost (T_a<0?C).

Seasonal pattern of phyllochron

Two groups of phyllochron were apparent when plotted against Pp on the day of first main-stem node appearance (Figure 2). For points were Pp was decreasing between 15.7 and 11.4?h the phyllochron decreased from 60–37?Cd (4.9?Cdh^{-1}). For all other data points a single phyllochron of 37???7?Cd was calculated with no slope detected (P = 0.23).

Discussion

Thermal time accumulation

The use of the $Tt_{b1/5}$ temperature threshold improved the description of main-stem node appearance compared with the Tt_{b5} threshold. Bi-linear temperature responses have also been used to quantify germination (Moot et al. 2000) and radical expansion (Masiunas and Carpenter 1984) of lucerne seedlings. Moot et al. (2001) showed the $Tt_{b1/5}$ threshold gave an improvement (relative to the Tt_{b5} threshold) in the accuracy of both main-stem node appearance and time of flowering simulations in Canterbury, New Zealand. The improvement with the bi-linear function may result from the actual response being curvilinear (Bonhomme 2000). This response is important in temperate environments where temperatures are close to T_b for a large proportion of the growth season.

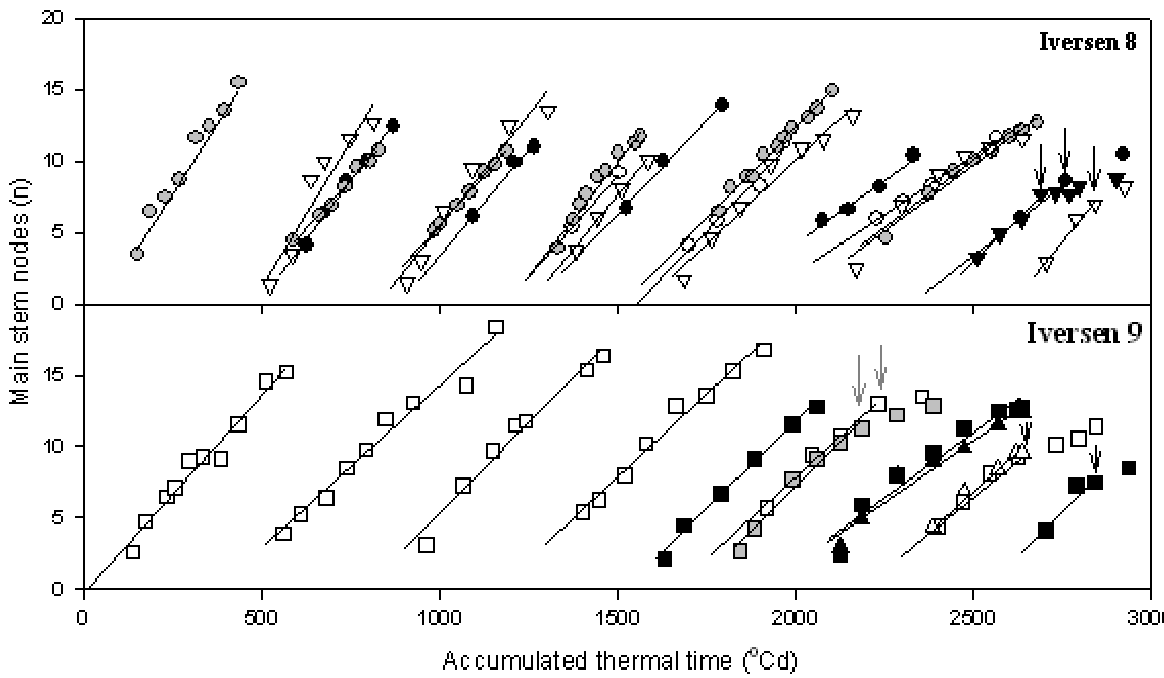

Figure 1. Main stem node appearance of regrowth 'Grasslands Kaituna' lucerne crops against thermal time (Tt) accumulated from 1 July for crops grown at Lincoln University, Canterbury, New Zealand. Black arrows mark days of < 0?C frosts, grey arrows indicate start of flowering in two crops. Different symbols represent different observation years.

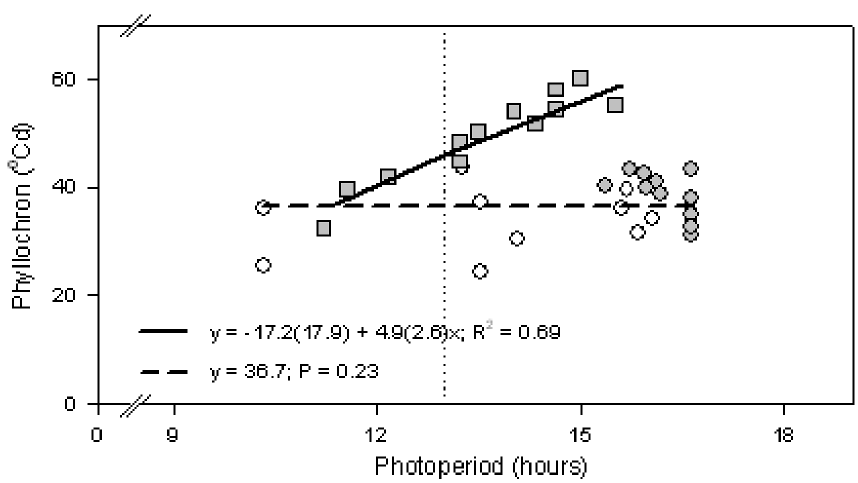

Figure 2. Phyllochron of regrowth 'Grasslands Kaituna' lucerne crops against photoperiod on the day of appearance of the first main-stem node at Lincoln University, Canterbury, New Zealand. White and grey symbols are from increasing and decreasing photoperiods, respectively.

Main-stem node appearance

Using the $Tt_{b/15}$ threshold gave a linear increase in main-stem nodes in relation to Tt accumulation within each regrowth cycle (Figure 1). This justifies the use of Tt accumulation and a phyllochron to simulate lucerne node appearance (Robertson et al. 2002). The onset of flowering and the occurrence of a T_a <0?C delayed or stopped main-stem node appearance all together (Figure 1). These effects will be important when lucerne is not defoliated or defoliated post-flowering and whenever the growth season is terminated by frosts.

Seasonal pattern of phyllochron

The seasonal pattern of phyllochron was related to Pp with the time of increased phyllochron coinciding with a decreasing Pp between 15.7 and 11.4?h at the time of first node appearance (Figure 2). A similar Pp response has been cited by Frame et al. (1998) where lucerne stem elongation decreased in response to shortening Pp. The current research also suggested the photoperiod response for lucerne phyllochron was induced near the beginning of the regrowth cycle (Brown 2004).

The regrowth cycles with the longest phyllochrons occurred in March and April and coincide with low autumn shoot growth and a reduced radiation use efficiency (Brown 2004). It is possible that the potential phyllochron was also 37??Cd during this period but the higher assimilate demand for root storage limited its expression. Alternatively node appearance could be directly responding to Pp and the resulting decreases in above ground assimilate demand enables greater root storage. Regardless of the mechanism these results highlight that a single phyllochron was inappropriate for 'Grasslands Kaituna' lucerne grown in a temperate environment.

Conclusions

This research has demonstrated a number of environmental responses that must be considered when simulating the LAI and subsequent growth of lucerne in a temperate climate.

- Main-stem node appearance showed a linear relationship with accumulated Tt within a regrowth cycle but phyllochron ranged from 30–60?Cd within a season.
- The phyllochron responded to Pp (at the time of first main-stem node appearance), decreasing from 60–37??Cd as Pp decreased from 15.7–11.4?h and remained ~37??Cd for the remainder of the season.

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