Impact of fall dormancy rating on phenological development of regrowth lucerne

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Abstract
To understand the influence of fall dormancy ratings (FD) on lucerne, we measured growth (shoot elongation), vegetative (phyllochron) and reproductive (bud initiation) development during the establishment year of three contrasting genotypes grown with irrigation at Lincoln University, Canterbury, New Zealand. A dormant (FD2), a semi-dormant (FD5), and a winter-active (FD10) lucerne genotype were first harvested at the end of their seedling phase in January 2015 and then subjected to defoliations at 42-day intervals from summer 2015 to spring 2016. Leaf count at harvest was consistent among genotypes but differed seasonally, ranging from 7 to 15 leaves. The phyllochron was also similar among genotypes at 37 GDD per primary leaf for regrowth and 52 GDD for seedling lucerne. Branching rates were also similar for all genotypes and followed a seasonal pattern similar to leaf appearance rates. Stem height at the end of each regrowth cycle was greater for FD10 compared with FD5 and FD2. Regrowth lucerne required shorter thermal time of 416 GDD to reach 50% bud initiation compared with 613 GDD in seedling lucerne. In summary, plant height was the only morphological feature that differed among genotypes with contrasting fall dormancy ratings. In contrast, the phyllochron, branching rates and bud initiation were conservative but responsive to environmental signals.

Keywords
Alfalfa, *Medicago sativa* L., shoot elongation, phyllochron, bud initiation.

Introduction
Fall dormancy (FD) is an important criterion used to classify lucerne (*Medicago sativa* L.) genotypes (Barnes et al. 1979). The FD rating for lucerne is based on stem height during autumn growth. However, physiological differences among genotypes are less well understood. For the seedling phase, Ta et al. (2016) suggested that stem height for a non-dormant genotype (FD10) was expressed after spring sowing and this resulted in greater seedling growth. It is unclear if this pattern is maintained during following regrowth cycles. This information can be used to validate breeders FD rankings for these genotypes. The objective of this research was to quantify the influence of FD on shoot elongation, phyllochron and bud initiation during multiple regrowth cycles.

Methods
The experiment was undertaken at Iversen Field, Field Research Center, Lincoln University, Canterbury, New Zealand in a split-plot randomised complete block design, with four replicates. The main-plots were three cutting intervals (28-, 42- and 84-days) and the sub-plots (20 x 4.2 m) were three genotypes with contrasting fall dormancy (FD): a dormant (FD2), a semi-dormant (FD5), and a winter-active (FD10). Lucerne was inoculated with NoduleN®, and sown on 8 October 2014. In this paper, only genotypes that received a 42-day cutting intervals were compared because this regime has been used in previous studies of grazing management in New Zealand (Moot et al. 2003). To do this, all lucerne crops were first harvested at the end of the seedling phase on 25 January 2015 and then defoliated at 42-day intervals. The experimental period was from summer (31 January 2015) to spring (16 October 2015). Five dominant shoots per genotype were tagged per plot to assess (i) the number of fully expanded primary leaves, (ii) shoot height (cm), (iii) the number of axillary leaves (branching), and (iv) the time of bud initiation at each main-shoot node. The phyllochron (GDD per primary leaf) was calculated based on daily thermal time (Tt, GDD) estimates using a broken-stick threshold model with base temperature of 1.0 °C (Jones and Kiniry 1986; Moot et al. 2001). This method calculates Tt at hourly intervals which are integrated over one day. Thermal time accumulation was calculated as the sum of daily Tt. Statistical analyses were performed using GenStat 16th edition (VSN International). The mean values were compared using Fisher's least significant difference, LSD (at P = 0.05).

Results

The number of leaves on the main shoot was similar among genotypes and within regrowth cycles (Figure 1). However, there was a seasonal pattern of change in leaf appearance rates. In summer, each genotype expanded up to 15 leaves but this decreased by 50% in winter, with 12 leaves in spring. The phyllochon for all genotypes was 37 GDD per primary leaf (P = 0.30). Branching rates were also similar (P = 0.31) for all genotypes and, similar to leaf appearance, showed strong seasonality (Figure 2). Branching ranged from a maximum of 12 axillary branches in summer to a minimum of 5 in winter. In contrast, plant height significantly (P < 0.05) differed among genotypes (Figure 3). The tallest plants were FD10 followed by FD5 and FD2. The plant height also differed seasonally with the tallest stems recorded for FD10 in summer (80 cm) and shortest for FD2 in winter (5 cm). As a consequence, the FD10 genotype had longer internodes (P < 0.05), which averaged 3.3 cm for FD10 compared with 2.3 cm for FD5 and 1.8 cm for FD2. For regrowth lucerne, the thermal time required to reach 50% bud initiation was consistent among genotypes at 416 ± 71.3 GDD. In seedling crops, thermal time at 50% bud initiation was 613 ± 31.3 GDD for all genotypes. During the 42-day regrowth cycles, genotypes did not reach the open flowering stage.

Discussion

Leaf appearance and branching rates showed a seasonal pattern and were not different among lucerne genotypes with contrasting FD ratings. Regrowth lucerne had a 38% shorter phyllochron than the 52 GDD previously found for the seedling phase (Ta et al. 2016). Similarly, regrowth lucerne consistently required a shorter thermal time interval to reach 50% bud initiation, in agreement with previous reports (Teixeira et al. 2011). The conservative results for vegetative (phyllochron) and reproductive (bud initiation) development across genotypes with contrasting FD indicate that differences were mainly attributed to the morphological components of shoot elongation. The FD10 genotype had taller shoots suggesting that more biomass was allocated into shoot growth, as illustrated by increased internode length. This strategy of elongating shoot length may result in higher individual shoot biomass (Ta et al. 2016) but potentially lower shoot quality because of increased lignification to support the extra height (Christian et al. 1970). These results align with breeders' rankings of FD values and provide a framework that could be used to introduce FD as a parameter in crop simulation models. How the increased height impacts on below-ground reserves remain to be assessed.

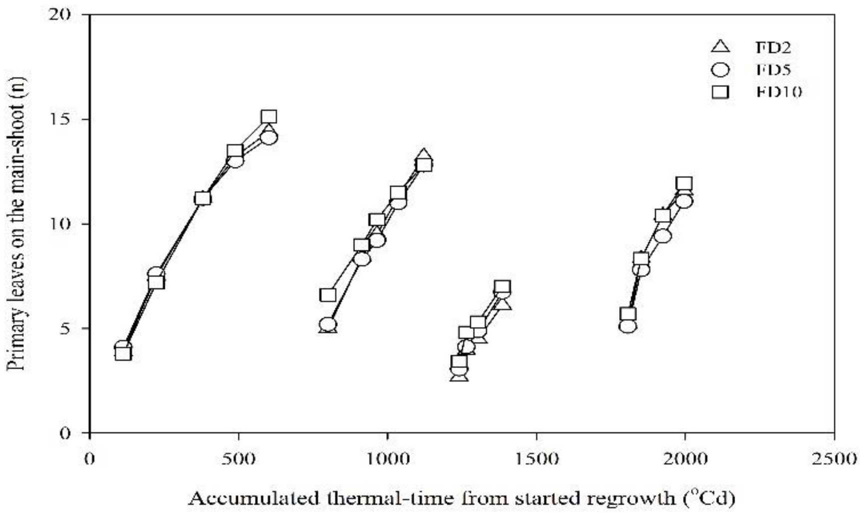

Figure 1. Number of primary leaves on the main-shoot during regrowth of three lucerne genotypes with contrasting fall dormancy ratings. Accumulated thermal time (GDD, base = 1.0°C) was calculated from 31 January 2015.

Conclusion

Stem height was the main morphological characteristic that differed among genotypes with contrasting FD. The taller shoots of FD10 were associated with longer internodes at each regrowth cycle. Leaf appearance and branching rates were not affected by FD ratings but differed seasonally. The phyllochron was also similar among genotypes. However, regrowth lucerne had a shorter phyllochron and required shorter time to reach bud initiation than seedling lucerne. These results confirm that plant height was most closely correlated with FD ratings. In contrast, the phyllochron and reproductive development were consistent among genotypes and affected by environmental signals.

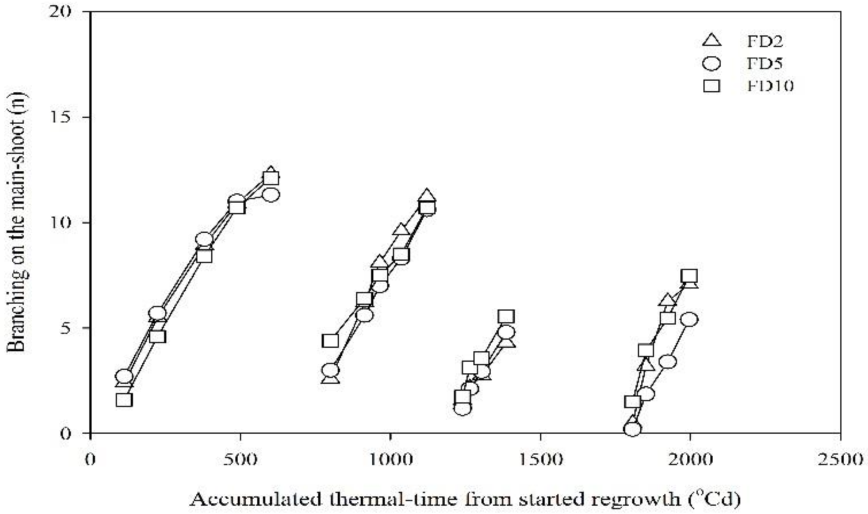

Figure 2. Number of branches on the main-shoot during regrowth of three lucerne genotypes with contrasting fall dormancy ratings. Accumulated thermal time (GDD, base = 1.0°C) was calculated from 31 January 2015.

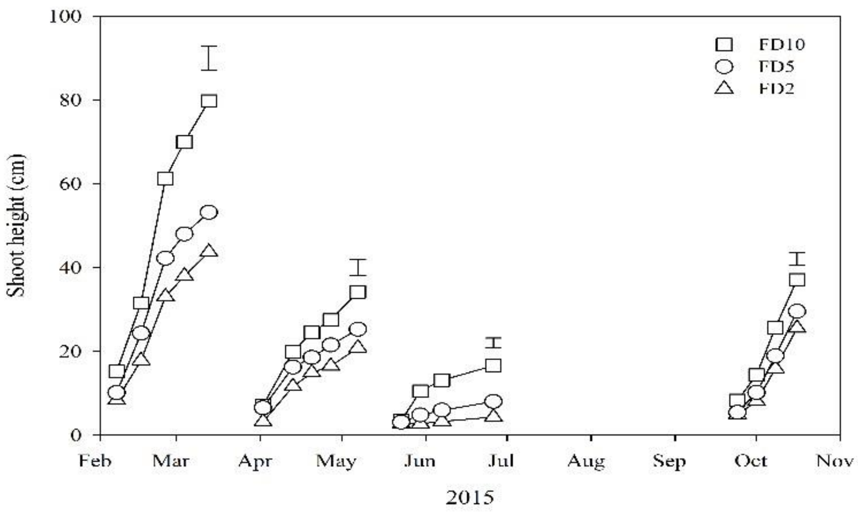

Figure 3. Shoot height during regrowth of three lucerne genotypes with contrasting fall dormancy ratings. Error bars represent LSD (P = 0.05) for each regrowth cycle.

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