Subterranean clover flowering time in New Zealand

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Abstract

Subterranean clover is a suitable legume for summer dry environments in New Zealand where rainfall is <900 mm/year. However, limited knowledge of its phenology, such as flowering time currently limits the development of best management practices to optimise plant growth while allowing adequate seed set under different environments. In this field study, four commercial Australian cultivars (‘Antas’, ‘Denmark’, ‘Leura’ and ‘Woogenellup’ were compared for flowering time across sowing dates. For all four cultivars the number of days to flower decreased ~30 % as the sowing date was delayed from February to May. The thermal time to flowering averaged 1944 ± 102.1 ºCd, or approximately 600 ºCd longer than in Australia. Flowering time was positively related (R^2=0.97) to temperature and modified by the photoperiod duration and direction. A model and weather parameters were used to predict flowering and safe grazing periods for Lincoln, Canterbury. The early establishment (February) provided the longest grazing period, up to 217±12.5 days while establishment in May had the shortest grazing period (122±8.0 days). The coefficients calculated should allow specific dryland management strategies to be tailored for different environments to optimise the time of grazing but still allow subterranean clover to flower and seed set.

Keywords

Phenology, management, prediction, thermal time, photoperiod.

Introduction

Traditional New Zealand pastures based on ryegrass (*Lolium perenne* L.) and white clover (*Trifolium repens* L.) are productive in areas with >1000 mm/year rainfall but are less reliable in lower rainfall systems (<900 mm/year) where 2-4 months of summer-dry conditions are expected. In these locations the winter-annual subterranean clover (*T. subterraneum* L.) can thrive (Moot, 2012; Smetham, 2003). As an annual species, the ongoing viability of subterranean clover depends on its ability to regenerate a sufficient plant population to reach flowering and set seeds to renew the population each autumn (Nichols et al., 2013). Optimal management to maximise subterranean clover vegetative growth, without compromising seed set, depends on knowing when flowering occurs. Defoliation through grazing can be timed to maximise vegetative intake but still allow flowering and seed set. Several studies suggest strong interactions between cultivar and environment in the control of flowering time (Brambilla et al., 2017; Evans et al., 1992). These imply that subterranean clover grazing must consider cultivar specific requirements for vegetative and reproductive development (Teixeira et al., 2017). Improved understanding of the interactions between the temperate New Zealand environment and imported subterranean clover cultivars is crucial to support dryland farmers’ adoption and management of subterranean clover based pastures. In this paper, the time of flowering of four commercial Australian cultivars was determined and the ideal grazing period identified for Canterbury, New Zealand.

Methods

Flowering dates

Subterranean clover flowering dates were measured in a field experiment at the Field Research Centre, Lincoln University (43.3857° S, 172.2804° E, 11 m.a.s.l.). Seeds of ‘Antas’, ‘Denmark’, ‘Leura’ and ‘Woogenellup’ which are considered mid-late maturity (Nichols et al. 2013; Teixeira et al. 2020d), were sown on 17 February, 15 March, and 4 May 2016 as monocultures in a split plot block design with three replicates. Five plants per plot were monitored (3-5 days interval) for flower appearance. The sowing dates represented a typical late summer-autumn sowing time, or period when an autumn break can be expected in eastern dryland areas of New Zealand (Teixeira et al. 2020d). Flowering was defined when ≥ 50 % of the assessed plants within the sub plot had at least one fully opened flower (R3, or stage 12 on the BBHC scale) (Enriquez-Hidalgo et al. 2020; Teixeira et al. 2020b).

Weather and thermal time

Temperature was recorded on site (Teixeira et al. 2020a). Thermal time (TT, °Cd) was calculated from the hourly recorded air temperatures (Jones & Kiniry, 1986) using a broken-stick relationship with cardinal temperatures representing base (Tb=0 ºC), lower optimum (18 ºC), upper optimum (22 ºC) and maximum (Tmax=36 ºC) thresholds (Teixeira et al. 2019; Teixeira et al. 2020d). Between May and August 2016 plants were exposed to 1870 hours below mean temperature of 10 ºC, fulfilling the vernalisation requirements (Morley & Evans, 1959). Daily photoperiod (including civil twilight) was calculated based on the day of the year and the location coordinates (Keisling, 1982). Mean photoperiod was considered between sowing to flowering as per Evans (1992) and ranged from 12.7 to 15.3 hours for the three sowing dates. The field data were used to derive a linear regression between thermal time and mean photoperiod (TT_{50F} = -5040(±225.9) + 487(±16.0)Pp, R^2=0.97 p<0.001). Data were assembled to estimate the time of flowering and the safe grazing period for subterranean clover grown at Lincoln using historical weather files (1980-2014) from New Zealand's National Climate Database (weather stations no. 4881,17603). Four establishment dates (February 01, March 01, April 01 and May 01) were considered based on the time of opening rains (20 mm) and the 'safe graze' start date (Moot et al., 2003; Chapman & Asseng, 2001). The grazing period (GP, as harvestable vegetative phase, days) was calculated as: GP (days) = $GED_{0.5}$ – GSD (±SE), where $GED_{0.5}$ is the graze end date 50 % of flowering and GSD is the graze start date (± standard error). Calculations and analysis were performed using R version 3.6.0 (R Core team, 2018).

Results

Time to 50 % flowering

For all four cultivars the time to flower decreased ~ 30 % as the sowing date was delayed from February to May (Figure 1). The mean number of days after sowing (DAS) to 50 % flowering was 223±9.0, the equivalent of 1944±102.1 ºCd).

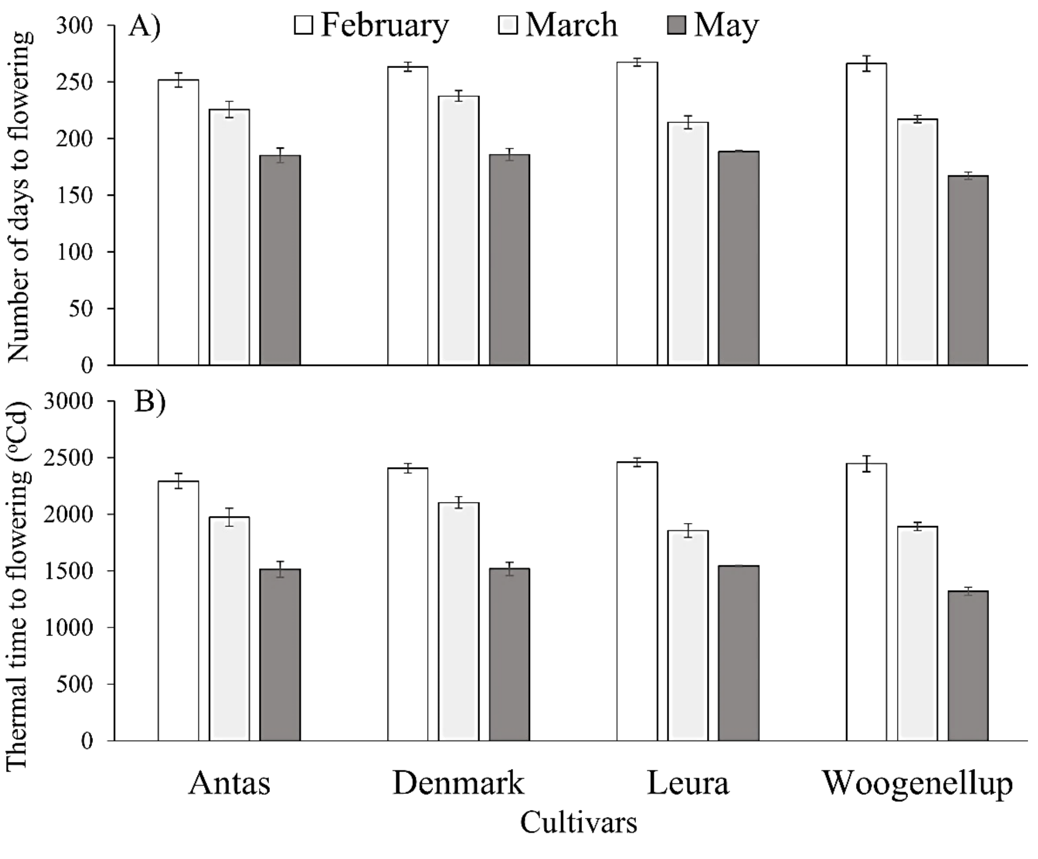

Figure 1.The (A) mean number of days and (B) thermal time (ºCd) to 50 % flowering for 'Antas', 'Denmark' 'Leura' and 'Woogenellup' when sown on the 17th February (□), 15th March (■) and 4th May 2016 (■). Bars represent the SE.

In Australia, a mean value of 155 days after sowing (~1285 ºCd) was determined for these cultivars to flower (Evans et al., 1992; Dear et al., 1993; Cocks & Phillips, 1979; Conboy & Hardwidge, 2009), when sown in autumn (a mean photoperiod of 13 ± 1 hours). Similarly, the Australian literature reports a decrease in time (days and thermal time) to flower when sowing date was delayed. For example, for 'Woogenellup' the mean number of days to flower was 185 (2005 ºCd) when sown in March in Wagga Wagga. When sowing was delayed until May, 'Woogenellup' required 150 days (1368 ºCd), or a reduction of 20 % in the time required to flower (Dear et al., 1993). This seasonal change in the time (days and thermal time) to flower implies temperature was the main driver of flowering, but photoperiodism influenced reproductive development. This ensures the plant remains vegetative immediately after emergence and so the time of safe grazing for establishing subterranean clover has been quantified as after seedlings have accumulated 5-6 trifoliate leaves, or around ~434 °Cd (Moot et al., 2003; Thomas 2003). Predicting how long this grazing can continue before flowering occurs requires observation of the plant life cycle, which can be followed visually (Teixeira et al., 2020c; Enriquez-Hidalgo et al., 2020a), combined with monitoring local weather data.

Safe grazing

The ability to graze subterranean clover in the winter is assisted by its positive geotropism, when it buries its seeds making them less vulnerable to grazing than top flowering clovers. However, graze events must be targeted prior to plants completing their reproductive phase to maximise the use of subterranean clover herbage in spring without compromising flowering and seed set (Ates et al., 2013). As expected, the earliest subterranean clover establishment provided the longest grazing period, up to 217±12.5 days (Table 1). On the other hand, the latest establishment date (May) resulted in the shortest grazing period (only 122±8.0 days), and results were consistent across cultivars. These results can be transferred to other environments to predict the duration of safe grazing, provided local weather records are available.

Table 1. Estimated chronological date (when grazing of subterranean clover plants can start and end for four establishment dates at two New Zealand locations.

Location	Establishment Date	GSD*	GDE_{05}**	Grazing period (days±SE)
Lincoln	01 Feb	27 Feb	01 Oct	217±12.5
	01 Mar	30 Mar	20 Sep	186±12.0
	01 Apr	08 May	13 Sep	133±2.5
	01 May	23 Jun	17 Oct	122±8.0

* Graze start date from Moot et al. 2003 **; Graze end date 50 % of flowering

Conclusion

The critical period to avoid over grazing subterranean clover is between emergence to fifth trifoliate leaves stage (the establishment phase) up until first flower and then burr burial to avoid removal of inflorescences which reduces seed set. Prediction of flowering and grazing time can assist farmers to identify when flower initiation is expected and to plan for grazing and paddock closure if seed set is required. Grazing periods can strategically defined according to specific cultivar x location scenarios, to ensure high seed set for subsequent reseeding.

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