Genotypic variation in vernalisation response and autumn growth in forage grass species

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Abstract

Depending on the grass species, development of stem-forming tillers is strictly regulated by temperature and/or day length (DL). We studied the regulation of tiller development and growth of timothy (*Phleum pratense* L.) and festulolium (*Festuca* × *Lolium*) by vernalisation, temperature and DL in field and growth chamber experiments. Our results show that there exists significant genotypic variation in traits important for biomass accumulation in different harvests. It seems that the extent of the spring growth flush is dependent on the vernalisation state of the plants. In autumn, growth in timothy is strictly regulated by DL, whereas in festulolium temperature is a more important regulator. Knowledge of these differences between grass species in their responses to environmental cues, and understanding of the genetic variation in these traits, provide unique opportunities for breeding as well as for the selection of best-performing genotypes for forage leys.

Keywords: adaptation, biomass, day length, festulolium, growth, timothy, vernalisation

Introduction

Climate change will affect silage production significantly in the future. In the Northern hemisphere the growing period will become longer and winters will become shorter. The adaptation of forage grass production to novel growing conditions will require new cultivars in which response to overwintering conditions (winter hardiness and vernalisation), day length (DL) and temperature are optimized.

Intensive silage production with frequent cutting during the growing season aims to provide high yields of herbage biomass with high nutritive quality. The number and weight of individual tillers determines the herbage yield. Stem-forming generative tillers are the heaviest and, in general, their proportion and digestibility determine the amount and quality of the silage yield (Virkajärvi *et al.*, 2012). The regulation of flowering varies between forage grass species so that the cultivated *Festuca* and *Lolium* species require double induction for flowering (vernalisation and long DL) whereas timothy can produce flowering tillers once the critical DL is exceeded (Heide, 1994). Also in timothy, vernalisation accelerates the development of flowering tillers (Jokela *et al.*, 2014) and the northern genotypes tend to be more responsive to both vernalisation and DL (Jokela *et al.*, 2015).

During winter, perennial forage grasses are exposed to vernalisation conditions resulting in release of stem growth and flowering (Seppänen *et al.*, 2010). Spring growth flush, which is a well-known phenomenon in forage grasses, is caused by rapid development of vernalized generative tillers (Seppänen *et al.*, 2010, Virkajärvi *et al.*, 2012). How the vernalisation requirement of a genotype affects herbage accumulation is yet not understood. It is known, however, that in timothy there exists substantial variation in vernalisation and DL requirement, and this variation could be utilized in breeding for adaptation to future growing conditions (V. Jokela, unpublished data).

Materials and methods

Vernalisation requirement was studied in field experiments during 2009-2013. Plant samples (n=4) were harvested from field-sown grass leys once a month during winter and the growth (number of tillers,

leaves and height) was monitored in a greenhouse (20/15 °C day/night, 16 h DL) until no change in the number of developing flowering or stem-forming tillers was observed. In separate growth chamber experiments, autumn growth (number of leaves and tillers, plant height and weight of tillers) was studied under three temperature (5, 10 or 15 °C) and two DL conditions (12, 14 h) resembling predicted future climate conditions. Genotypes of different origin as well as breeding lines and cultivars of timothy and festulolium were used in the experiments. The plant material used in each experiment is indicated in the selected results that are reported here. Timothy breeding lines of southern and northern origin were kindly provided by Boreal Plant Breeding Ltd, Finland, and Festulolium breeding lines by Graminor Ltd., Norway.

Results and discussion

Vernalisation affected height growth and potential for yield formation in timothy (Figure 1a). Genotypes of southern origin were able to produce generative tillers by November, whereas the northern or intermediate types with longer vernalisation requirements started stem growth in January and were dormant until then. It also seemed that long winter and too-long vernalisation time decreased the yield potential, as development became faster and the developed flowering tillers were shorter in May than in January (Figure 1a). Stem elongation is mainly related to fulfilment of vernalisation requirement although adequate DL is also necessary in timothy (Jokela *et al.*, 2014).

Biomass accumulation in autumn can be a result of an increase in the number and weight of leaves and shoots or height growth. We exposed timothy and festulolium genotypes to different DL and temperature conditions resembling predicted future conditions during autumn growth (Figure 1b.). Shorter DL decreased the biomass accumulation in both timothy and festulolium. In timothy DL regulated height growth, and genotypes of southern origin having shorter DL requirement for flowering were able to produce elongating true tillers at 14 h (data not shown). Our results show that the critical DL for flowering (Heide, 1994) is correlated with the genotype's ability to accumulate biomass during short DL in autumn. Timothy seemed to be more sensitive to growth temperature than festulolium, and in timothy there existed variation between southern and northern genotypes in their growth at low temperature (10 °C, 5 °C). In contrast, festulolium genotypes of northern and southern origin accumulated biomass under these conditions rather similarly. This was mainly due to increased weight of individual tillers.

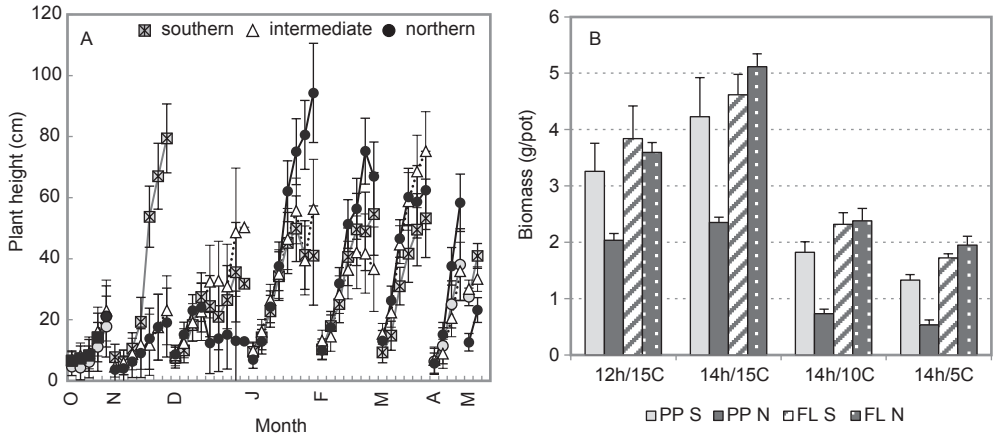

Figure 1. (a) The effect of vernalisation on height growth of timothy cultivars during winter. Samples were harvested once a month from the field and the height growth was monitored in a greenhouse. (b) Biomass accumulation of timothy (PP S- southern, PP N – northern) and festulolium (FL S –southern, FL-N northern) genotypes at different day length (12 and 14 h) and temperature (5, 10 and 15 °C).

Conclusions

In timothy, a wide variation in vernalisation requirement and DL response was found between genotypes. Southern cultivars had a shorter vernalisation requirement, which was demonstrated by an earlier release of stem growth during winter. However, a long vernalisation period during winter diminished these genotypic differences. Experiments on autumn growth revealed that timothy genotypes were more responsive than festulolium to both temperature and DL. At low growing temperature and short DL, biomass accumulation was modest in the northern timothy genotype. In contrast, northern festulolium genotypes also accumulated relatively high amounts of biomass at short DL (15 °C) and no differences between genotypes of northern and southern origin were observed. Our results have demonstrated that genetic variation exists between and within forage grass species. This variation could be utilized in grass breeding for adaptation to future climate conditions.

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