# Identifying target traits for forage grass breeding under a changing climate in Norway using the BASGRA model

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## Introduction

Grass-based dairy and livestock production constitutes the most important agricultural sector in Norway in economic terms, and 60% of the agricultural land in Norway is used for grass production. Climate change may have considerable impact on the survival and productivity of grasslands, with consequences for the local supply of forage to livestock, farmers' income and the supply of dairy- and livestock-based food products to the global market. Farmers can adapt to climate change by choosing different grass species or cultivars or by changing management practices such as the timing and frequency of harvests. Plant breeders select new cultivars of grasses that are better suited to a specific environment and management practices by utilizing available resources in the most optimal way. A key characteristic for grass cultivars grown in Norway is their ability to survive the winter, a characteristic that will remain important also in the future (Thorsen and Höglind 2010). Winter hardy cultivars contribute to high and stable yields, and minimize the need for costly reseeding. Other desired traits for grass cultivars in Norway are high nutritive value of the herbage, high tolerance of the plants to frequent cutting and grazing, and good suitability for conservation through ensiling. Breeding for a new grass cultivar usually takes 15-20 years. It is difficult to predict which trait combinations will be important in the future, especially under climate change conditions. However, it is important to define breeding targets and investigate the underlying genetic and physiological mechanisms of important traits.

Process-based simulation models for grass can be used to evaluate the effects of altered plant traits under projected climate change conditions. Here we show an example with preliminary results from a study where the BASGRA model was used to evaluate the effect of modified plant characteristics on grass winter survival and yield under projected climate change conditions for Norway.

## Methods

Timothy (*Phleum pratense* L.) and perennial ryegrass (*Lolium perenne* L.) were simulated for three locations in Norway: Apelsvoll (60°42'N; 10°52'E), Sola (58°53'N; 5°38'E) and Tromsø (69°41'N; 18°55'E), and three periods 1961-1990 (baseline), 2046-2065, and 2080-2099 using the BASGRA model. This is an updated version of the LINGA model (van Oijen 2005) to which winter processes like cold hardening and tiller mortality due to frost and ice has been added (Thorsen and Höglind 2010; Höglind *et al*. 2013). Daily weather data were generated with the LARS-WG tool (Semenov 2008) incorporating projections from 12 General Circulation Models (GCMs). For each scenario, grass performance was first simulated for a current cultivar, and then for cultivars with altered traits.

The altered traits included: (1) increased maximum frost tolerance by 4 ºC; and (2) an extension of one month of the period during which rehardening is possible. The maximum frost tolerance represents the genetic potential, which may or may not be realized during the winter season depending on the conditions for cold hardening. Low temperatures are necessary for cold hardening. When cold hardened plants are subject to mild weather, the frost tolerance is gradually lost, a processed called dehardening. If the temperature falls again, the plant may increase their frost tolerance again in a process called rehardening. However, the ability to reharden is gradually lost as the winter progress at a rate which may differ between genotypes. The effects of increasing the frost tolerance and extending the rehardening capacity were evaluated by calculating the number of frost kill events per season, *i.e.* the number of days when the simulated temperature at the soil surface fell below the simulated frost tolerance of the plant.

For timothy, the effect of altered phenology was also simulated. The reproductive development was delayed so that the timothy cultivar with altered traits reached the early-heading stage 12-15 days later than the current cultivar. The effect of the delayed reproductive development on the dry matter yield of the first cut and the total seasonal yield was assessed.

## Results and discussion

The results showed clear differences between the current cultivars and those with altered traits. For perennial ryegrass, increasing the maximum frost tolerance decreased the number of frost kill events relatively more than extending the rehardening period. The effects of altering these two cultivar traits were relatively higher under projected future climate conditions than under current conditions. For timothy, there were only very few frost kill events regardless of climate conditions or cultivar traits. Further studies will include a number of other traits related to winter survival, such as temperature and day-length sensitivity of growth cessation and hardening during the autumn, temperature sensitivity of photosynthesis and respiration during the winter, minimum frost tolerance, and ice encasement tolerance.

The phenological change in timothy increased the dry matter yield in the first harvest, but did not affect the total seasonal dry matter yield. Further studies could include the effect of changed development rate on forage quality. Hereditability and competing breeding goals will be included in the final analysis.

## Conclusion

The preliminary results from this simulations study indicate that a high maximum frost tolerance will be important for winter survival in perennial ryegrass also under future climate conditions in Norway. Delayed reproductive development in spring will have limited effect on the total seasonal yield.

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## References

Höglind M, Thorsen SM, Semenov MA (2013) Assessing uncertainties in impact of climate change on grass production in Northern Europe using ensembles of global climate models. *Agricultural and Forest Meteorology* **170**, 103-113.

Semenov MA (2008) Simulation of extreme weather events by a stochastic weather generator. *Climate Research* **35**, 203-212.

Thorsen SM, Höglind M (2010) Assessing winter survival of forage grasses in Norway under future climate scenarios by simulating potential frost tolerance in combination with simple agroclimatic indices. *Agricultural and Forest Meteorology* **150**, 1272-1282.

Van Oijen M, Höglind M, Hanslin HM, Caldwell N (2005) Process-based modelling of timothy regrowth. *Agronomy Journal* **97**, 1295-1303.