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Functional overwintering types as basis for modelling the overwintering of northern field layer plants under climate warming

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Highlights: Three overwintering types were identified among boreal field layer plants by using growth chamber experiments in combination with phenological dynamic models of the annual cycle. These types form the basis for modelling the responses of overwintering plants to climate change.

Keywords: Climate warming, chilling, dormancy, dynamic models, functional types, growth onset.

The environmental conditions of plants are projected to change globally during the coming decades due to climate change. The changes are predicted to be especially pronounced in the north during the winter. This will bring about novel combinations of environmental factors not experienced by contemporary plants. Experimental determination of the effect of various climate change scenarios on plants are often limited by the resources and effort needed to carry out multiple treatments. This shortcoming can, in part, be overcome by the use of ecophysiological process-based dynamic models. The successful use of dynamic models in climate change research requires that the models are properly tested and parameterised by experimental data.

Towards winter, many plants enter a state of rest, or endodormancy, which is maintained physiologically, and gradually released by the effect of chilling. Endodormancy is followed by ecodormancy, during which microscopic ontogenetic development towards growth onset is taking place in the buds in response to temperature. Growth onset results in physiological changes in the plant, such as loss of freezing tolerance, which can be detrimental if the plants start growing prematurely during warm spells in winter.

By modifying phenological dynamic models of the annual cycle of forest trees (Hänninen 1990, Hänninen and Kramer 2007), we developed dynamic models for the overwintering of perennial field layer plants in the boreal zone with the purpose of identifying functional overwintering types among these in order to create tools to study the effects of wintertime climate change on field layer plants in the boreal zone. The models were parameterised by using data from a series of growth chamber experiments with plants representing different functional groups from dwarf shrubs, hemicryptophytes, overwintering rosette plants, and grasses. The plants were allowed to overwinter in constant conditions in freezer storage at -2.5 °C. At various times in winter, plants were transferred to growth chambers to constant or fluctuating temperatures, and the onset of growth was monitored. Based on these results, we identified overwintering types that form the basis of both modelling and experimental work.

Our results show that there are differences among both plant species and functional groups in the timing of growth onset following warm periods in the winter. Several responses regarding timing of growth onset could be seen. Three overwintering types could be identified based mainly on the amount of chilling required to break endodormancy, determined by using dynamic models of overwintering. These overwintering types are characterized by having shallow, moderate or deep endodormancy, respectively. The identified types agree with types previously defined in the literature (Yoshie and Yoshida 1989). Considerable variation can, however, be found among species within the types, e.g. with respect to the rate of ontogenetic development.

Premature growth onset during winter affects other physiological traits such as plant cold hardiness and carbon metabolism. Differential responses among species may result in changes in species composition. Dynamic process-based models of the overwintering responses of plants can also be incorporated in larger scale models and thus used to refine predictions of the consequences of climate change on the vegetation.

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