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A fifty-year-old conceptual plant dormancy model provides new insights into dynamic phenology modelling

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Highlights: Vegis' (1964) conceptual plant dormancy model has been largely ignored in dynamic models of growth onset phenology. We formulate a dynamic model including the phenomenon assumed in the conceptual model and show that the phenomenon 1) potentially explains previous contradictory results of model testing and 2) is crucial with respect to the effects of climate warming on boreal trees.

Keywords: Bud burst, chilling, climate warming, dormancy, frost damage, growth onset

Air temperature has in boreal and temperate trees two major effects regulating the timing of growth onset. Firstly, prolonged exposure to chilling temperatures is required for removing the growth arresting physiological conditions in the buds. Secondly, exposure to high forcing temperatures causes microscopic ontogenetic development in the buds so that a prolonged exposure causes visible growth onset. Since the 1970s both the chilling and the forcing effect have been addressed in dynamic models of growth onset. In these models chilling changes the dormancy status of the bud and the changing dormancy status in turn changes the air temperature response of ontogenetic development. Before the chilling requirement is met either no ontogenetic development takes place, or more realistically the ontogenetic development takes place at a reduced rate. No interaction of the dormancy status and the prevailing forcing temperature is included so that accumulation of chilling affects the rate of ontogenetic development similarly regardless of the forcing temperature. In other words, chilling affects the level of the air temperature response curve of ontogenetic development, but not its location on the air temperature axis. Based on the ideas included in Vegis' (1964) conceptual model we introduce a novel model including such interaction. According to the original conceptual model the growth promoting temperature range changes as a result of the changing dormancy status so that as a result of chilling growth is possible in gradually lower temperatures. The conceptual model found support in a recent experimental study with two *Betula* species (Junttila and Hänninen 2012). We extend the original model to cover also the rate of ontogenetic development and formulate a dynamic model based on this extension. In our model the air temperature response curve moves towards lower temperatures as a result of chilling accumulation. Using simulations with air temperature data from both experimental and natural conditions we show that the phenomenon assumed in the extended model is potentially able to explain earlier contradictory results where the current models have found support in experimental tests but not in tests carried out with long-term phenological records from natural conditions. Using simulations with scenario air temperature data we further show that the phenomenon reduces the risk of frost damage caused by a premature growth onset under climatic warming. Based on these findings from simulation studies we conclude that the phenomenon described in the extended model should be tested experimentally with a wide variety of tree and other plant species.

LITERATURE CITED

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