Dear Dr. Surridge:

Please consider our manuscript, "How interactive effects of temperature and photoperiod shape plant phenology responses to warming," for publication as a Review in *Nature Plants*. This article draws on long-term obervations, controlled environment experiments and physiological advances at the cellular level to outline a path forward for studies of plant phenology.

Climate change has led to growing research in phenology—a fundamental process of plant biology that influences carbon storage and climate change itself. Much of this research, however, has progressed without a strong connection to the basic biology of phenology. This disconnect may explain why recent trends in spring phenology have failed to match predictions based on simple linear models (Fu *et al.*, 2015; Piao *et al.*, 2017). In contrast, decades of controlled environment studies show that responses will be non-linear because of the cues that determine spring plant phenology (forcing, chilling, and photoperiod).

We show why a greater integration across fields will be critical for accurate forecasts of plant phenology. Our review highlights how researchers could better harness the power of controlled environment experiments to transform our fundamental understanding of phenology and advance forecasting. Controlled environment studies can critically rule out, or support, hypotheses to explain observed discrepancies in long-term data and open up new pathways to understand current trends. While understanding, modeling and predicting interactions among cues and their effects on phenology is challenging, it will yield more accurate predictions—with valuable implications to more realistically assess the effects of climate change on plant biodiversity, including agricultural and forest species.

This review includes a meta-analysis of seven decades of controlled environment studies to understand the cue-space (i.e., the possible range of each cue and interactions across cues) already studied, and how it compares to current and future conditions. Based on this, we outline a cross-disciplinary path forward where advances in physiology (e.g., Singh *et al.*, 2019; Chang *et al.*, 2021), greater integration of controlled environment studies with forecasting, and multi-species modeling can yield more robust predictions.

Upon acceptance for publication, data from a systematic literature review included in the paper will be freely available at KNB (knb.ecoinformatics.org); the full dataset is available to reviewers and editors upon request. All authors substantially contributed to this work and approved of this version for submission. The manuscript is approximately 4050 words with 181 word abstract, five figures, and 94 references. It is not under consideration elsewhere. We hope that you will find it suitable for publication in *Nature Plants* and look forward to hearing from you.

Sincerely,

Elizabeth M Wolkovich
Associate Professor of Forest & Conservation Sciences
University of British Columbia

*References:*


Chang, C.Y.Y., Brautigam, K., Huner, N.P.A. & Ensminger, I. (2021) Champions of winter survival: cold acclimation and molecular regulation of cold hardiness in evergreen conifers. *New Phytologist* **229**, 675–691.

Fu, Y.S.H., Zhao, H.F., Piao, S.L., Peaucelle, M., Peng, S.S., Zhou, G.Y., Ciais, P., Huang, M.T., Menzel, A., Uelas, J.P., Song, Y., Vitasse, Y., Zeng, Z.Z. & Janssens, I.A. (2015) Declining global warming effects on the phenology of spring leaf unfolding. *Nature* **526**, 104–107.

Piao, S., Liu, Z., Wang, T., Peng, S., Ciais, P., Huang, M., Ahlstrom, A., Burkhart, J.F., Chevallier, F., Janssens, I.A. *et al.* (2017) Weakening temperature control on the interannual variations of spring carbon uptake across northern lands. *Nature climate change* **7**, 359.

Singh, R.K., Miskolczi, P., Maurya, J.P. & Bhalerao, R.P. (2019) A tree ortholog of short vegetative phase floral repressor mediates photoperiodic control of bud dormancy. *Current Biology* **29**, 128–+.