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Historic and Future Winter Chill for Temperate Fruit Trees and Knowledge Constraints to Orchard Planning

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Abstract

Temperate fruit and nut trees require particular climatic conditions during all seasons to produce yields that allow commercial orchard operations. The most critical requirement in warm temperate and subtropical regions is winter chill, of which a certain quantity must be accumulated for trees to break dormancy and resume regular growth in spring. Different models exist for quantifying winter chill, but they differ greatly in accuracy and sensitivity to temperature change. All models are empirical proxies, which are not founded on thorough understanding of tree physiology. This casts doubts on their suitability for climate change projections. The problems associated with this range of models are illustrated using a global dataset of winter chill, based on temperature records from more than 5000 weather stations around the world, and supported by more detailed studies in California's Central Valley and in high-altitude oases in Oman. Results show that winter chill models are not equivalent, and the relationships between the various chill metrics are strongly dependent on temperature. Accordingly, projected winter chill for climate change scenarios depends primarily on the choice of model, casting doubts on the usefulness of many projections done in the past. The most robust model across temperature gradients appears to be the Dynamic Model, developed in Israel, one of the world's warmest growing regions. Based on a dataset of more than 4000 weather stations worldwide and on 20 climate scenarios, historic and likely future decline in winter chill was identified for warm growing regions. Orchards in North and South Africa, Southern Europe, Southern Australia and other subtropical regions, as well as in the Tropical highlands, appear particularly at risk. Temperate regions are projected to experience relatively stable conditions, while cold regions could even see increasing chill. The accuracy of such projections, and thus the ability of orchard managers to plan cultivar succession, is constrained by substantial knowledge gaps about tree dormancy. Long-term phenology records and innovative statistical tools, most notably projection-to-latent-structures regression, can help close some of these gaps, but extensive experimentation is also needed to ensure that high-value orchards remain viable in a gradually warming future.

Keywords: Chill portions, chilling hours, climate change, dynamic model, phenology, winter chill

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