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Modelling frost and heat impact on yields: challenges and perspectives

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Abstract: Frost and heat events occurring during sensitive crop growth stages can lead to substantial yield losses. The frequency and intensity of these temperature extremes are increasing in many broadacre cropping regions due to climate change, posing significant challenges to agricultural productivity. In cool-season grain-growing areas, where summer temperatures are already high, the combined risks of frost and heat constrain adaptation strategies. Accurately representing these stresses in crop models is essential for assessing the timing, severity, and yield impacts of extreme temperature events. Despite this need, most existing process-based crop models were not developed to simulate short-duration temperature extremes, limiting their capacity to evaluate climate-related risks and support adaptation planning. Crop models are able to model different species, including cultivar differences (notably phenology). Still, some environmental stresses, such as the impact of frost and heat on yields, are yet to be modelled. Yield reductions from frost and heat are primarily linked to physiological responses such as pollen sterility, grain abortion, accelerated senescence, and impaired grain filling. Improving model representation of these processes is critical for enhancing the reliability of simulations under increasingly variable climatic conditions. Six challenges limit current modelling approaches: (1) inadequate spatial and temporal resolution of temperature data for extreme events, (2) threshold-based and non-linear crop responses, (3) interactions between phenology and management, (4) cumulative and interacting stress effects across development stages, (5) limited representation of genotype-specific sensitivities, and (6) reliance on daily maximum and minimum temperature data. Addressing these challenges requires improved use of sub-daily climate data, incorporation of physiological damage mechanisms, and enhanced crop- and genotype-specific parameterisation (Richetti et al., 2025). These improvements are critical for enhancing crop yield predictions under extreme temperatures in the context of climate change.

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