

**Supplementary Materials to the Manuscript:  
Combining temperate fruit tree cultivars to fit spring  
phenology models**

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9      **Abstract**

10     Phenological datasets for temperate fruit trees are often short , fragmented and  
 11    geographically restricted, which hampers the development of cultivar-specific  
 12    spring phenology models. To address this, we propose a novel calibration approach  
 13    (“combined-fitting”), which pools observations from several cultivars of the same  
 14    species, distinguishing between shared and cultivar-specific parameters. This method  
 15    requires fewer observations per cultivar and allows jointly analyzing cultivars of  
 16    the same species. We evaluate combined-fitting using the PhenoFlex framework,  
 17    comparing it to a baseline model and to models that are fitted only with data for  
 18    single cultivars (“cultivar-fit”). Our analysis is based on flowering data from nine  
 19    almond, six apricot and six sweet cherry cultivars across Mediterranean (Spain,  
 20    Morocco, Tunisia) and German climates. The combined-fit model failed to achieve  
 21    higher prediction accuracy compared to the cultivar-fit and the baseline approach,  
 22    as evidenced by similar root mean square errors across the data splits and calibra-  
 23    tion dataset sizes. When comparing the estimated parameters of the chill and heat  
 24    accumulation submodels, we observed a large variation among cultivars of the same  
 25    species in the cultivar-fit models. In contrast and by design, the combined-fit yielded  
 26    only one parameter set for cultivars of the same species. Our findings demonstrate  
 27    that integrating data from multiple cultivars can yield spring phenology models  
 28    with high accuracy. Even though the combined-fit approach did not outperform the  
 29    cultivar-fit approach, combined-fitting offers a practical solution for spring phenology  
 30    modeling with limited datasets and facilitates comparison across cultivars of the  
 31    same species.

32      **1 Introduction**

33     This document contains supplementary materials for the journal article: *Combining*  
 34    *temperate fruit tree cultivar to fit spring phenology models*. It contains some extra  
 35    tables and files that were not included in the main article. Also, it contains code  
 36    snippets that help the reader to replicate parts of the analyses.

37     The phenology data that we analyse is part of a long-term phenology dataset  
 38    (Luedeling, Caspersen, Delgado Delgado, et al., 2024) compiled by the *Adapting*  
 39    *Mediterranean Orchards (AdaMedOr)* project. Of the more than 270 cultivars  
 40    comprised by the dataset, a subset of 110 cultivars has been analyzed with the  
 41    PhenoFlex framework (Luedeling et al., 2021), available via the R package *chillR*  
 42    (Luedeling, Caspersen, & Fernandez, 2024). The analysis contains next to model  
 43    calibration also climate change impact projections on future bloom dates (Caspersen  
 44    et al., 2025).

45     More than 50% of the cultivars in the dataset were not analysed, because the bloom  
 46    observations were deemed too short to be analysed with PhenoFlex. We propose an  
 47    alternative calibration method called combine-fitting, that reduces the number of  
 48    model parameters estimated per cultivar and may allow the joined analysis too short  
 49    for conventional model calibration. We evaluate the method for three temperate  
 50    fruit and nut trees (almond, apricot, sweet cherry) and compared the results with a  
 51    baseline model and a common calibration approach where each cultivar is calibrated  
 52    separately. We perform the analysis for the full dataset and an artificially shortened  
 53    dataset.

54     Parts of the function that we present in this document are available via the R pack-  
 55    ages *evalpheno* (Caspersen, 2025a) and *LarsChill* (Caspersen, 2025b). Both packages  
 56    are currently available via GitHub.

57 **2 Preparing Bloom Data**

58 This notebook shows the preparation of the phenology data. Performs calibration  
59 and validation data splits. Check out the notebook for more details:

60 [Split data in calibration and validation](#)

61 **3 Model Calibration**

62 These three notebooks perform the model calibration. The notebook for almond cal-  
63 ibration has also some more comments on the different procedures. The notebooks  
64 for apricot and sweet cherry only contain the uncommented code.

- 65 • Almond calibration
- 66 • Apricot calibration
- 67 • Sweet Cherry calibration

68 **4 Model Evaluation**

69 This code shows how the calibrated models are evaluated. This script generates  
70 figures and tables for the manuscript.

71 [Generate figures for the manuscript](#)

72 **References**

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