The ARNOLD ARBORETUM of HARVARD UNIVERSITY

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Dear Dear Editors:

Please consider our paper, entitled "Phenological sequences: how early-season events define those that follow" for publication as a "Brief Communication " in the *American Journal of Botany.*

Phenology, or the timing of life events such as spring flowering and leafout, has gained increasing prominence in ecology as one of the most widely documented biological impacts of anthropogenic climate change (1-3) . Early spring phenology has generally shifted earlier with warmer temperatures (1,4) , but phenology later in the season (late spring flowering, summer fruiting, fall senescence) is less studied and may be more variable (5). Accurate forecasting of phenology across the growing season is desirable because phenology is critical for important natural resources, as well as for predictions of future climate change, through its role in the global carbon cycle. The length of the growing season (i.e., from spring leaf-out to fall senescence) feeds in to global carbon models, and affects forest productivity. In addition, the timing of flowering is critical for pollinators, and the timing of fruitset is essential to many vertebrate consumers, such as migratory birds.

An important, but poorly studied, aspect of plant phenology is that phenological events are inherently linked through their order: leaf budburst typically occurs before flowering, and flowering always precedes fruiting. This ordering may constrain how some phenological events can respond to climate change. However, the extent to which previous phenological events are correlated with later phenological events is not known because few studies to date have integrated across multiple phenological events within a growing season. Instead, previous studies have focused either on events related to leaf phenology (including spring budburst, leafout, and fall senescence), or reproductive events, especially flowering (6) .

In this paper, we offer the first study reporting on observations of consecutive phenophases from the start through the end of the growing season, across 25 temperate tree species with divergent flowering phenology, grown in a common environment. We test if previous phenological events constrain later events; e.g., do late-fruiting species set fruit late in the season because they flower and leafout late? In addition, we test whether interphase duration constrains phenology; e.g., do late-fruiting species set fruit late in the season because they require longer fruit maturation time? We find strong effects of both early phenology and interphase duration, highlighting the need to include previous phenological information when forecasting future phenology.

Our findings have implications that are broadly important for improved understanding of plant phenology, and for forecasting climate change induced shifts in phenology. For example, our finding that early phenological events constrain later events suggests that climatic shifts in one season, even if they directly affect only one phenophase, will have cascading effects on phenology later in the season. We suggest as potential reviewers David Inouye, Allison Donnelly, Nicole Rafferty, Paul CaraDonna and Amy Iler. Thank you for your time and consideration of our paper.

Sincerely,

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