

Patterns in Flowering, Leafing-Out, and Fruit Ripening in Eastern Redbud, *Cercis canadensis* Linnaeus, 1753 (Fabaceae) Documented through the Nature's Notebook Campaign, The Redbud Phenology Project: 2021 to the Present¹

Theresa M. Crimmins², Jorge A. Santiago-Blay³, Samantha Brewer², McKinsey Tighe², and Erin E. Posthumus²

Abstract: Herein, we present a synopsis of the current finds in our phenology study on eastern North America redbud, *Cercis canadensis*. With the assistance of over 200 citizen scientists that have been using *Nature's Notebook* online platform since 2020, we can now begin to glean broad phenological patterns of *C. canadensis* in the USA and Canada. Within this region, leaf and flower buds begin to open between early April and mid-May. Fruits are ripe from mid-July to mid-May of the following year.

Key words: *Cercis canadensis*, eastern North America redbuds, phenology, The Redbud Phenology Project, *Nature's Notebook*, USA National Phenology Network, biodiversity, leaf-out, flowering, fruit ripening

Introduction

Eastern North America redbud, *Cercis canadensis* Linnaeus, 1753 (Fabaceae), is a common, generally understory, short-lived (20-30 years; Raulston 1990, Gilman et al. 2019), deciduous forest tree (Adkins et al. 2012, Banner and Stein 2008, Dickson 1990, Dirr et al. 1998; Dirr and Warren 2019, Flynn and Holder 2001, Kress 2024, Robertson 1976). Although it is not considered a species valuable for timber, its relatively small size (typically not exceeding 15 meters, circa 50 feet), early spring flowering, as well as numerous varieties and cultivars has made it a valuable ornamental tree, widely distributed in the USA and increasingly, worldwide (Dirr et al. 1998, Kidwell-Slack and Pooler 2018). Besides its desirable ornamental qualities and economic values (Hall and Ingram 2014, Riley et al. 2018), there is evidence that *C. canadensis* serves as a source of nectar, pollen, and nesting materials to numerous insects,

¹ Submitted on July 19, 2024. Accepted on August 24, 2024. Final revisions received on December 28, 2024.

² USA National Phenology Network, School of Natural Resources and the Environment, University of Arizona, Tucson, Arizona 85721 USA. E-mails: theresam@arizona.edu , samantha@usanpn.org , mckinsey@usanpn.org , and erin@usanpn.org , respectively.

³ Research Associate, Department of Paleobiology, National Museum of Natural History, MRC-121, 10th and Constitution Avenue, Washington, District of Columbia, USA. Email: blayj@si.edu .

<https://blaypublishers.com/wp-content/uploads/2024/12/crimmins-7.pdf>

Electronically available on December 29, 2024. Mailed on December 31, 2024.

particularly bees (Koeser et al. 2022, Lovell 1961, Serrano 2005) as well as food to mammals and birds (Anonymous, no date; Ottaviano et al. 2023) helping sustain a complex biodiversity web (Frey 2021, Santiago-Blay et al. 2021).

The *Nature's Notebook* platform (www.naturesnotebook.org), hosted by the USA National Phenology Network (USA-NPN), is designed for use by professional and volunteer observers, independently or as part of an organized group (Rosemartin et al. 2014, Crimmins et al. 2020). The platform consists of standardized observation protocols, a mobile app for data collection, an online interface for submitting and accessing observations, and data visualization and download tools. The USA National Phenology Network offers extensive training materials in multiple formats, sends frequent, information-rich messages to participants through email and social media, and customizes website content to feature and enhance collaborators' data collection efforts. In addition, USA-NPN staff offer ample in-person and virtual support to new and existing participants to recruit and retain participants in collecting data of the highest possible quality. Over the 17 years that *Nature's Notebook* has been in existence, over 25,000 observers have submitted approximately 40 million observations from over 18,000 sites on thousands of plant and animal taxa. These data are used extensively in scientific studies and to support real-time decision-making (Crimmins et al. 2022).

The USA-NPN protocols embedded in *Nature's Notebook* are “status” protocols, meaning that participants are asked to report on the status of life cycle stages for an individual plant or animal species each time they make an observation and to make observations frequently over the course of the growing season (Denny et al. 2014, Denny and Crimmins 2022). Each plant phenology observation is composed of “yes” or “no” responses to a series of questions pertaining to the state of a plant's leaves, flowers, and fruits (Figure 1).

The Redbud Phenology Project (<https://www.usanpn.org/nm/campaigns/Redbud>), a *Nature's Notebook* observing campaign, was initiated in 2021 and formally launched in 2022. The aim of the campaign is to enable an improved understanding of when redbud trees flower and fruit across their range, how the timing of these events is affected by latitude and elevation, and whether the timing of these events has advanced in recent years. The campaign is widely advertised through emails to *Nature's Notebook* participants and other volunteer networks, in-person presentations, and through scientific publications (Brewer and Santiago-Blay 2022a, b; Posthumus et al. 2021; Posthumus and Santiago-Blay 2021; Tighe et al. 2024). USA National Phenology Network staff and campaign leads host a kick-off webinar each winter (December or January) to recruit new participants and introduce them to the basics of observing. Campaign participants are

emailed approximately every six weeks during the growing season with project updates, data summaries, other news related to redbuds, and the human touch of heartily felt encouragement.





Phenophase	Definition	Photo (click to enlarge)
Flowers or flower buds	One or more fresh open or unopened flowers or flower buds are visible on the plant. Include flower buds or inflorescences that are swelling or expanding, but do not include those that are tightly closed and not actively growing (dormant). Also do not include wilted or dried flowers.	
Open flowers	One or more open, fresh flowers are visible on the plant. Flowers are considered "open" when the reproductive parts (male stamens or female pistils) are visible between or within unfolded or open flower parts (petals, floral tubes or sepals). Do not include wilted or dried flowers.	
Fruits	One or more fruits are visible on the plant. For <i>Cercis canadensis</i> , the fruit is a pod that changes from green to purplish to dark brown and, over time, splits open to expose the seeds. Do not include empty pods that have already dropped all of their seeds.	
Ripe fruits	One or more ripe fruits are visible on the plant. For <i>Cercis canadensis</i> , a fruit is considered ripe when it has turned dark brown. Do not include empty pods that have already dropped all of their seeds.	
Recent fruit or seed drop	One or more mature fruits or seeds have dropped or been removed from the plant since your last visit. Do not include obviously immature fruits that have dropped before ripening, such as in a heavy rain or wind, or empty fruits that had long ago dropped all of their seeds but remained on the plant.	

Figure 1. Status protocol for observing Eastern redbud in *Nature's Notebook*, available at <https://www.usanpn.org/nn/campaigns/Redbud> .

Here, we provide a summary of the observations contributed by *Nature's Notebook* participants on redbud leaf-out, flowering, and fruiting phenology. These findings are valuable for characterizing the general timing of these events in redbud across the species' range. As well, this information provides a critical foundation for increasing understanding of the climate factors that cue these events and in determining whether the timing of these events is shifting in response to changing climate conditions, as is occurring with so many plant species around the globe.

Results

The Redbud Phenology Campaign has led to a dramatic increase in the number of observation sites and observations reported to *Nature's Notebook* (Figures 2, 3). Since the initiation of a redbud-focused *Nature's Notebook* project in 2021, the number of sites and the number of phenological reports submitted have more than doubled. Prior to the project launch, between 30 and 80 sites reported on redbud phenology; following project launch, this number rose from 120 to over 220 sites (Figure 2).

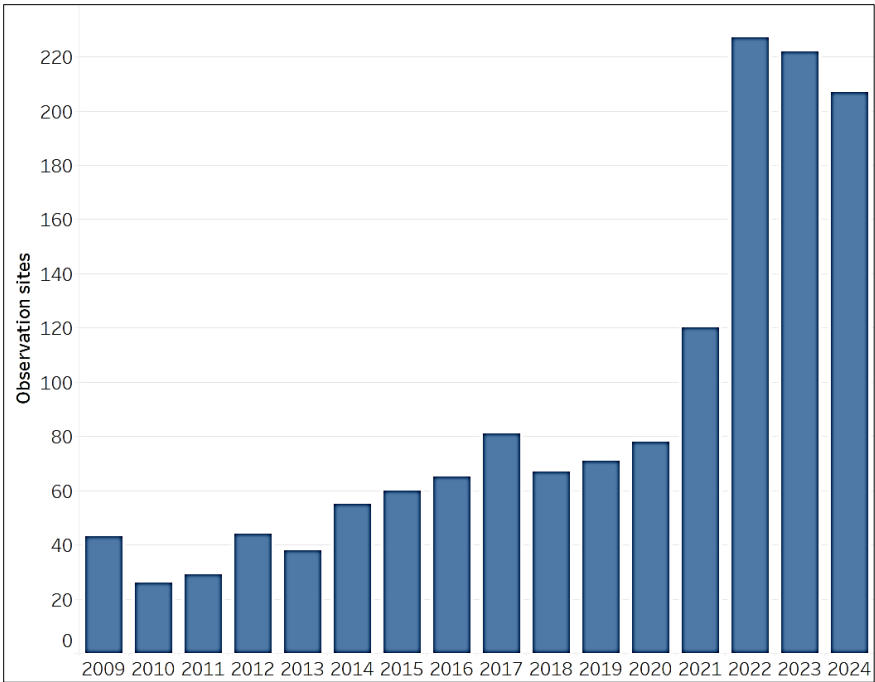


Figure 2. Sites reporting redbud phenological status in *Nature's Notebook*, 2009-2024.

The increase in phenological reports submitted to *Nature's Notebook* enables a richer examination of the spatial and temporal patterns in activity in this tree. Below, we summarize the leafing-out, flowering, and fruit ripening patterns collected through *Nature's Notebook* for eastern redbud, *C. canadensis*, since 2021.

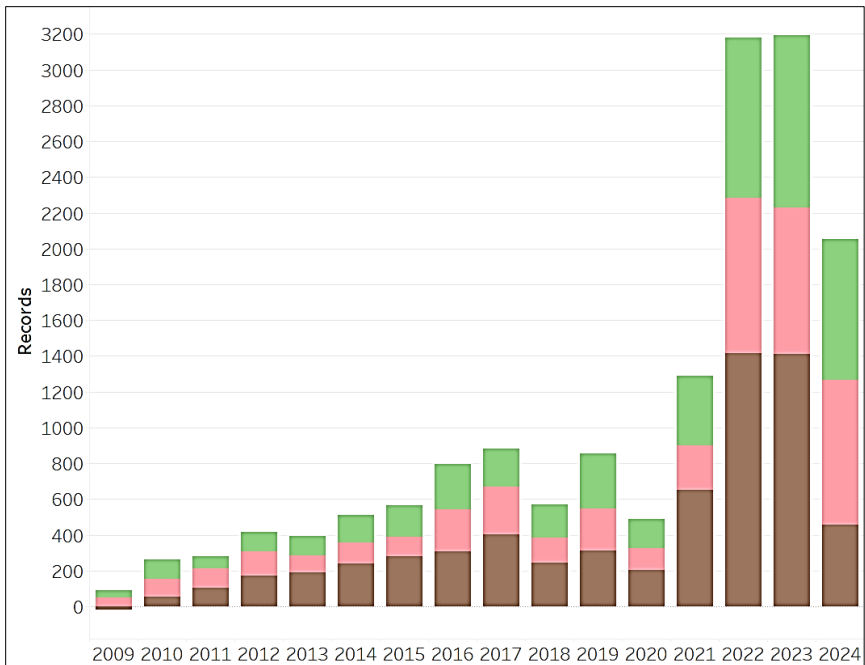


Figure 3. Status reports for “breaking leaf buds” (green), “open flowers” (pink), and “ripe fruits” (brown) submitted to *Nature’s Notebook* for eastern redbud, 2009-2024.

Flowering

In general, trees at lower latitudes flower earlier in the year than those at higher latitudes (Figure 4). Similar to breaking leaf buds, the period when “open flowers” are reported varies from year to year (Figure 5); in recent years, reports have been concentrated between day of year 100 (April 9) and 140 (May 19). The interannual variability in the timing of flowering is reflected in Figure 6, which shows the proportion of “yes” reports for “open flowers” in the four most recent years. Peak date was notably later in 2022 than in 2021 and 2023.

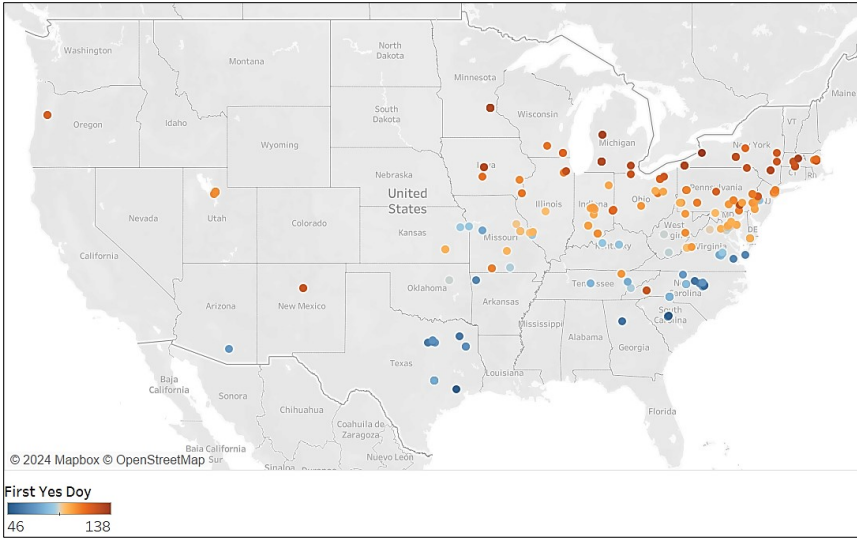


Figure 4. Day of year “open flowers” were first reported for redbud trees observed using *Nature’s Notebook*, 2021-2024.

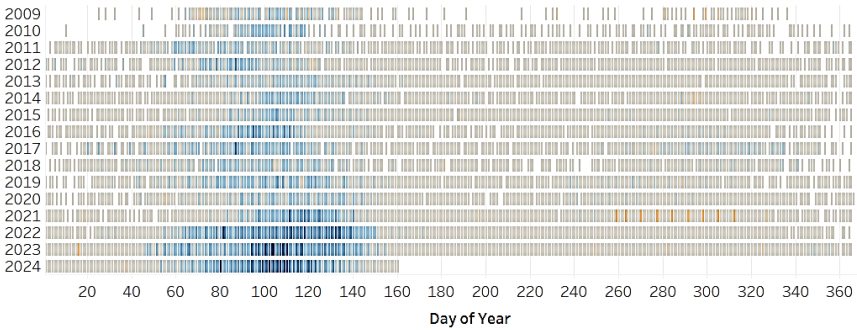


Figure 5. Phenophase status reports for “open flowers” in redbuds reported to *Nature’s Notebook*, 2009-2024. Blue = “yes” reports, grey = “no” reports, orange = “not sure” reports.

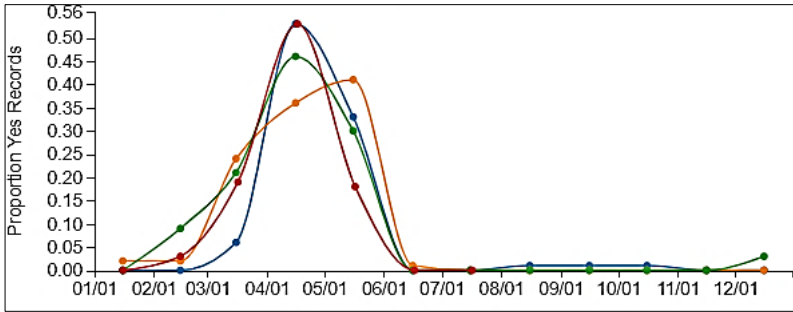


Figure 6. Proportion of “yes” reports for “open flowers” in eastern redbud, 2021 (blue), 2022 (orange), 2023 (green), and 2024 (red).

Breaking leaf buds

As with flowering, leaf buds break earlier in the year at lower latitudes and later at higher latitudes (Figure 7). The period when breaking leaf buds are reported varies from year to year (Figure 8); in recent years, reports have been concentrated between day of year 100 (April 9) and 140 (May 19). The interannual variability in the date of peak leaf-out is reflected in Figure 9, which shows the proportion of “yes” reports for “breaking leaf buds” in the four most recent years. Peak date was notably later in 2022 than in 2021 and 2023.

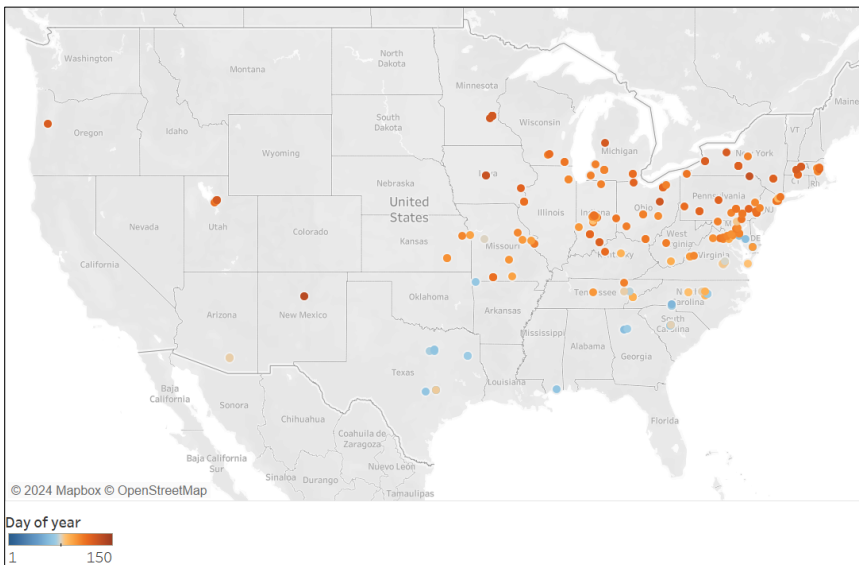


Figure 7. Day of year “breaking leaf buds” were first reported for redbud trees observed using *Nature’s Notebook*, 2021-2024.

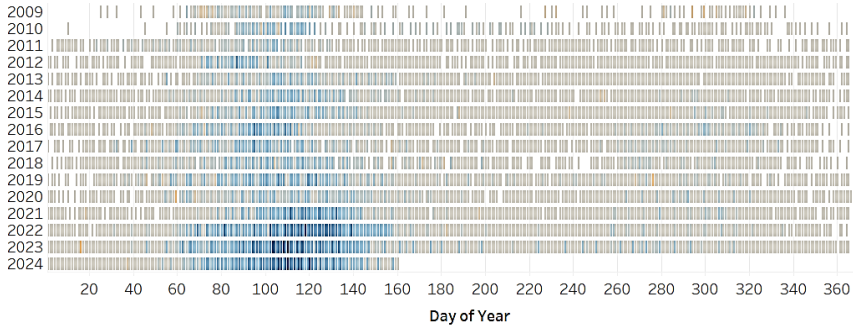


Figure 8. Phenophase status reports for “breaking leaf buds” in redbuds reported to *Nature’s Notebook*, 2009-2024. Blue = “yes” reports, grey = “no” reports, orange = “not sure” reports.

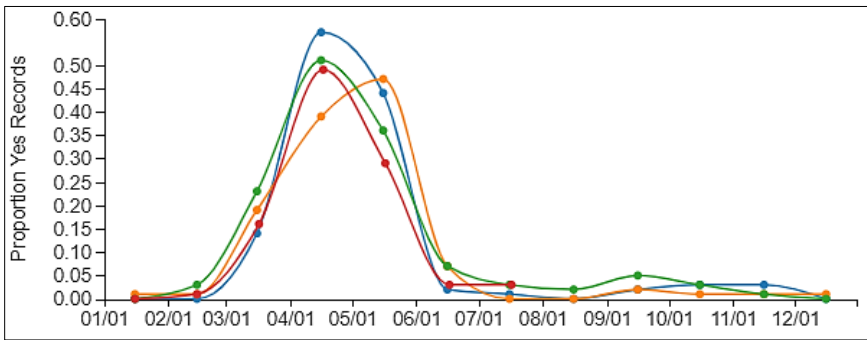


Figure 9. Proportion of “yes” reports for “breaking leaf buds” in eastern redbud, 2021 (blue), 2022 (orange), 2023 (green), and 2024 (red).

Ripe fruits

The dates ripe fruits are reported do not follow as clear of a latitudinal pattern as leaf-out and flowering (Figure 10). The period when breaking leaf buds are reported varies from year to year (Figure 11); in recent years, reports have been concentrated between day of year 240 (August 27) and 320 (November 15). The interannual variability in the timing of ripe fruits is reflected in Figure 12, which shows the proportion of “yes” reports for “ripe fruits” in the four most recent years. While the onset of fruit ripening does not show clear temporal variation among years (Figure 11), a larger proportion of individual trees exhibiting ripe fruits were reported earlier in 2021 than 2022 and 2023 (Figure 12). In many years, ripe fruits have been reported well into December (Figures 11, 12). Redbud trees retain seed pods well into the

following spring. *Nature's Notebook* observers are advised to keep reporting “yes” to “ripe fruits” as long as they can feel seeds within the seed pods.

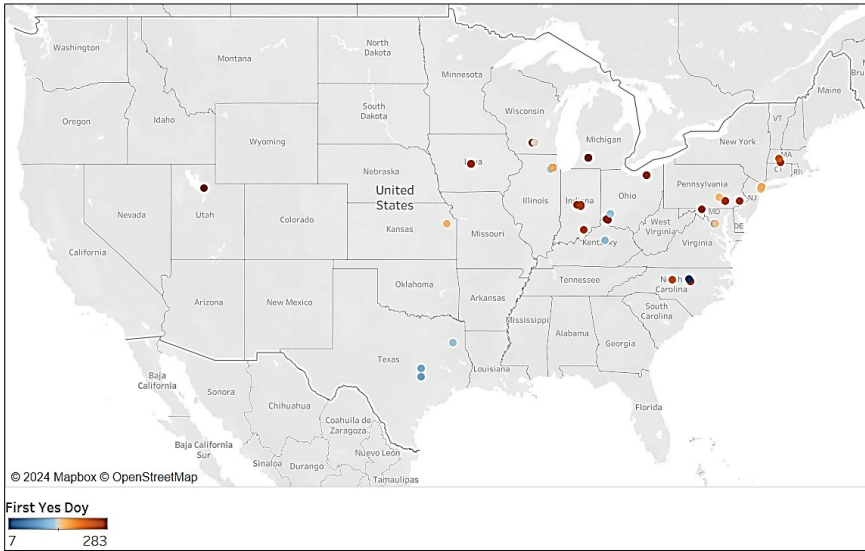


Figure 10. Day of year “ripe fruits” were first reported for redbud trees observed using *Nature's Notebook*, 2021-2024.

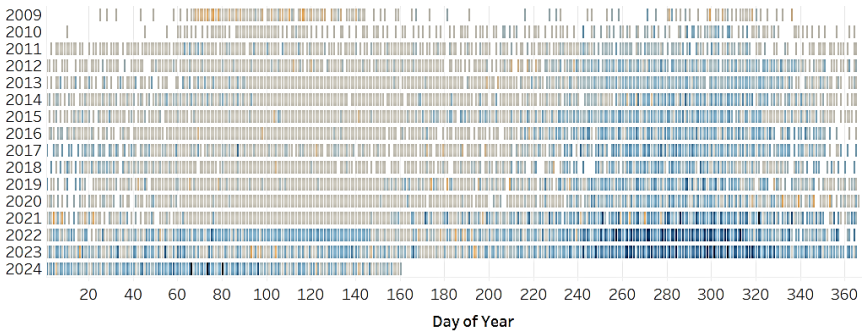


Figure 11. Phenophase status reports for “ripe fruits” in redbuds reported to *Nature's Notebook*, 2009-2024. Blue = “yes” reports, grey = “no” reports, orange = “not sure” reports.

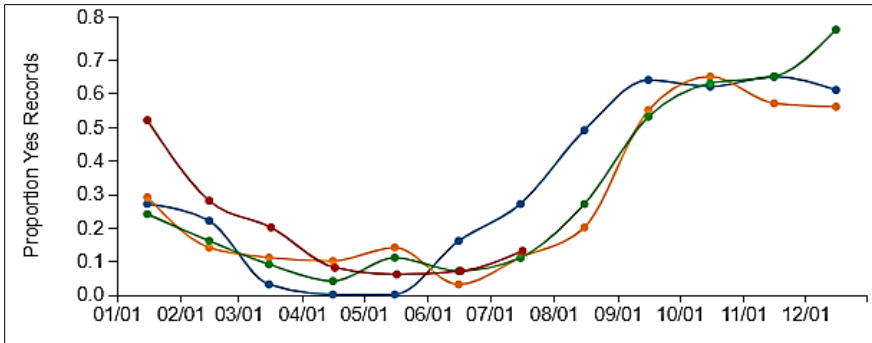


Figure 12. Proportion of “yes” reports for “ripe fruits” in eastern redbud, 2021 (blue), 2022 (orange), 2023 (green), and 2024 (red).

Discussion

This report characterizes spatial and temporal patterns in leafing-out, flowering, and fruit ripening in eastern redbud, *Cercis canadensis*, in the United States. Through a *Nature’s Notebook* campaign coordinated by USA National Phenology Network staff and collaborators based at Penn State York, we have amassed over 300,000 records of the timing of activity in this tree.

These observations reveal clear patterns in the timing of leaf bud break, flowering, and fruit ripening. Interestingly, the patterns are not wholly consistent among the three phenophases evaluated. While flowering and leaf-out peaked notably later in 2022 than in the other years summarized, this pattern did not hold for the peak in ripe fruits. Rather, a larger proportion of redbud trees exhibited ripe fruits earlier in 2021 than in the other years evaluated; the timing of ripe fruit reports in 2022 better matched that of 2023. The earlier leaf and flower activity observed in 2022 may be the result of the comparatively cool spring temperatures recorded across the eastern U.S. in this year, in contrast to quite warm and early spring conditions recorded in at least part of the tree’s range in 2021, 2023, and 2024 (USA National Phenology Network Status of Spring maps, 2024).

In this write-up, we have limited our analyses to characterizing general patterns. Additional work will evaluate the influence of latitude, elevation, and other environmental variables. Also, we plan to place these recent observations into a longer historical context to evaluate change in the timing or abundance of flowering or fruiting. However, this initial documentation of patterns lays an important foundation for future analyses to determine whether the timing of these events is being affected by changing climate conditions.

Acknowledgments

We wholeheartedly thank the over 200 citizen scientists in the USA and Canada, who have reported on redbud in the *Nature's Notebook* online platform, without whom this project could not have been possible and well as to the personnel associated to the numerous social media venues that have allowed us to promote this research. We thank the two anonymous reviewers who made helpful suggestions to improve the manuscript.

Literature Cited

- Adkins, C. R., N. A. Ward, S. K. Bramer, and S. A. White, S.A. 2012. Chapter 12. Redbud – *Cercis* spp., pp. 287-303. In, Flucher, A. F. and S. A. White (Editors). *IPM for Select Deciduous Trees in Southeastern US Nursery Production*. Southern Nursery IPM Working Group Knoxville, Tennessee, USA. 326 pp. https://web.archive.org/web/20160212111703/http://www.clemson.edu/extension/horticulture/nursery/ipm/ipm_book.html
- Anonymous. No date. *Cercis canadensis*. In Gardening Help. Plant Finder. Missouri Botanical Garden. <https://www.missouribotanicalgarden.org/PlantFinder/PlantFinderDetails.aspx?taxonid=280440&isprofile=1&basic=cercis%20canadensis>
- Banner, V.A. and W. I. Stien, 2008. *Cercis* L. pp. 374-380. In, *Woody Plant Seed Manual*. United States Department of Agriculture Forest Service Agricultural Handbook 727. 1,223 https://www.fs.usda.gov/nsl/nsl_wpsm.html
- Brewer, S. and J. A. Santiago-Blay. 2022a. The Redbud Phenology Project: Fall 2022 Update for Citizen Scientists and Anyone Interested. *Life: The Excitement of Biology* 10(1):66-68. DOI:10.9784/LEB10(1)Brewer.01
- Brewer, S. and J. A. Santiago-Blay. 2022b. The Redbud Phenology Project: The November 2022 Update. *Life: The Excitement of Biology* 10(2):96-99. DOI:10.9784/LEB10(2)Brewer.01
- Crimmins, T. M., L. Barnett, E. G. Denny, A. H. Rosemartin, S. Schaffer, and J.F. Weltzin. 2020. From tiny acorns grow mighty oaks: what we've learned from nurturing *Nature's Notebook*. pp 191-222. In: *Handbook of Citizen Science in Ecology and Conservation*. Instead, I suggest this: C. A. Lepczyk., O. D. Boyle., and T. L. V. Vargo (Editors). R. F. Noss (Foreword). University of California Press. Oakland, California, USA. xviii + 313 pp. <https://doi.org/10.2307/j.ctvz0h8fz.20>
- Crimmins, T. M., E. G. Denny, E. E. Posthumus, A. H. Rosemartin, R. Croll, M. Montano, and H. Panci. 2022. Science and management advancements made possible by the USA National Phenology Network's *Nature's Notebook* platform. *BioScience* 72(9): 908-920. <https://doi.org/10.1093/biosci/biac061>
- Denny, E. G. and T. M. Crimmins. 2023. Updates to standardized plant and animal observation protocols of the USA National Phenology Network. *International Journal of Biometeorology* 67(5):927-930. <https://doi.org/10.1007/s00484-023-02444-0>
- Denny, E. G., K. L. Gerst, A. J. Miller-Rushing, G. L. Tierney, T. M. Crimmins, C. A. F. Enquist, P. Guertin, A. H. Rosemartin, M. D. Schwartz, K. A. Thomas, and J. F. Weltzin. 2014. Standardized phenology monitoring methods to track plants and animal activity for science and resource management applications. *International Journal of Biometeorology* 58:591-601. <https://doi.org/10.1007/s00484-014-0789-5>
- Dickson, J. 1990. *Cercis canadensis* L. pp. 266–269. In, Burns R. and B. Honkala B. (Editors). *Silvics of North America: 1. Conifers; 2. Hardwoods*. Agriculture Handbook 654. United States Department of Agriculture, Forest Service. Washington, District of Columbia, USA. Two volumes. 877 pp.
- Dirr, M. A. (Illustrations by B. Dirr, M. Stephan, A. Sadauskas, and N. Snyder). 2009. *Manual of Woody Landscape Plants. Their Identification, Ornamental Characteristics, Culture, Propagation and Uses*. Sixth Edition. Stipes Publishing L.L.C. Champaign, Illinois, USA. 1,325 pp.

- Dirr, M. A. and K. S. Warren. 2019. *The Tree Book. Superior Selections for Landscapes, Streetscapes, and Gardens*. Timber Press, Inc. Portland, Oregon, USA. 939 pp.
- Flynn, J. H. Jr. and C. D. Holder. (Editors). 2001. *A Guide to Useful Woods of the World*. Second Edition: Forest Products Society. Madison, Wisconsin, USA. 618 pp.
- Frey, K. A. 2021. Engaging volunteers of a Pennsylvanian county park in research through scholarly collaborations. *Life: The Excitement of Biology* 9(1):24-26. https://blaypublishers.com/wp-content/uploads/2021/12/frey_leb9131dec.21.pdf
- Gilman, E. F., D. G. Watson, R. W. Klein, A. K. Koeser, D. R. Hilbert, and D. C. McLean. 2019. *Cercis canadensis*: Eastern Redbud. IFAS Extension. University of Florida. Gainesville, Florida, USA. Publication # ENH304/ST145. 4 pp. <https://edis.ifas.ufl.edu/publication/ST145>
- Hall, C. R. and D. Ingram. 2014. Production costs of field-grown *Cercis canadensis* L.'Forest Pansy' identified during life cycle assessment analysis. *HortScience*. 49(5): 622-627. <https://doi.org/10.21273/HORTSCI.49.5.622>
- Kidwell-Slak, D. and M. Pooler. 2018. A Checklist of *Cercis* (Redbud) Cultivars. *HortScience* 53(2):148-152. <https://doi.org/10.21273/HORTSCI12564-17>
- Koeser, A. K., G. Hassing, M. H. Friedman, and R. B. Irving. 2022. Eastern Redbud. *Trees: North & Central Florida. A Field Guide to 140 Tree Species*. Institute of Food and Agricultural Sciences. University of Florida. Gainesville, Florida, USA. 370 pp.
- Kress, W. J. (Foreword by M. D. Lowman). 2024. *Smithsonian Trees of North America*. Yale University Press. New Haven, Connecticut, USA. 800 pp.
- Lovell, H. B. 1961. Let's talk about honey plants. *Gleanings Bee Culture* 89(2):99-100.
- Ottaviano, K., J. Dixon, and J. A. Santiago-Blay. 2023. Wind dispersal of eastern redbud, *Cercis canadensis* Linnaeus (Fabaceae), seedpods. *Life: The Excitement of Biology* 11(2):40-56. https://blaypublishers.com/wp-content/uploads/2023/12/ottaviano_leb_112-1.pdf.
- Posthumus, E., T. Crimmins, and J. A. Santiago-Blay 2021. Participate in Citizen Science: The Redbud Project. *Life: The Excitement of Biology* 9(1):27-28. DOI:10.9784/LEB9(1)Posthumus.01
- Posthumus, E. and J. A. Santiago-Blay 2021. The Redbud Phenology Project: An Update. *Life: The Excitement of Biology* 9(2):83-86. DOI: 10.9784/LEB9(2)Posthumus.01
- Raulston, J. C. 1990. Redbud. *American Nurseryman* 171(5):39-51.
- Riley, C. B., D. A. Herms, and M. M. Gardiner. 2018. Exotic trees contribute to urban forest diversity and ecosystem services in inner-city Cleveland, OH. *Urban Forestry & Urban Greening* 29:367-376. <https://doi.org/10.1016/j.ufug.2017.01.004>
- Robertson, K. R. 1976. *Cercis*: The Redbuds. *Arnoldia* 2:37-49. <https://doi.org/10.1353/hph.2008.0415>
- Rosemartin, A. H., T. M. Crimmins, C. A. F. Enquist, K. L. Gerst, J. L. Kellermann, E. E. Posthumus, J. F. Weltzin, E. G. Denny, P. Guertin, and L. Marsh. 2014. Organizing phenological data resources to inform natural resource conservation. *Biological Conservation* 173:90-97. <https://doi.org/10.1016/j.biocon.2013.07.003>
- Santiago-Blay, J. A., K. L. Samms, M. Kocher, I. Shandoor, E. Perago, F. Alashoor, L. Ohl, A. Zahra, K. Bartos, R. Ohl, and A. Bishay. 2022 ["2021"]. Twelve new records of bees (Hymenoptera: Apoidea: Anthophila) for York County, Pennsylvania, USA: A Progress Report. *Life: The Excitement of Biology* 9(2):029-041. https://blaypublishers.files.wordpress.com/2022/03/santiago-blay_et_al_leb_92-1.pdf
- Serrano, D. 2005. Leafcutting bees, Megachilidae (Insecta: Hymenoptera: Megachilidae: Megachilinae). *Featured Creatures*. EENY342. Entomology and Nematology Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences (IFAS), University of Florida. Gainesville, Florida, USA. 3 pp.
- Tighe, M., S. Brewer, and J. A. Santiago-Blay. 2024. The Redbud, *Cercis canadensis* Linnaeus, 1753 and *Cercis occidentalis* (Fabaceae) Torrey ex A. Gray (1850), Phenology Project. *Life: The Excitement of Biology* 11(3):96-99. https://blaypublishers.com/wp-content/uploads/2024/02/tighe_et_al_leb_113-2.pdf
- USA National Phenology Network Status of Spring maps, 2021-2024. <https://www.usanpn.org/data/maps/spring>