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Tracking the climate-influenced north temperate radiation of the grape genus using genomic data

By Jun Wen, Richard Hodel, Zelong Nie, and Gary Krupnick

As a research botanist and curator for almost 20 years at the National Museum of Natural History (NMNH), Jun Wen has been studying the biogeography of the northern hemisphere and the biogeographic relationships between temperate and tropical elements. She has been actively studying the origin and evolution of eastern Asian and eastern North American disjunct biogeographic pattern in flowering plants since her graduate school days. Wen and her team of colleagues have shown a special interest in the grape genus *Vitis* (Vitaceae), from which she and her collaborators have been collecting specimens during recent field expeditions in the United States, Mexico, and China. The broad geographic sampling of the grape genus has enabled using this group of plants as a model for improving our understanding of plant biogeography and evolution in temperate North America.

The north temperate region was characterized by a warm climate and a rich thermophilic flora before the Eocene, but the early diversifications of the temperate biome under global climate change and biome shift remain uncertain. A recent paper by Wen and colleagues from the Chinese Academy of Sciences, Huazhong Agricultural University, Jishou University, University of Alaska Fairbanks, and NMNH used the grape genus *Vitis* as a model to unravel the diversification of this economically highly important lineage of plants and provide insights into the temporal and spatial evolution of plants in temperate North America. The paper, "Climate-influenced boreotropical survival and rampant introgressions explain the thriving of New World grapes in the north temperate zone," was published in *Journal of Integrative Plant Biology* (65: 1183-1203; https://doi.org/10.1111/jipb.13466) and authored by the

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Hybridization potentially represents one of the most important mechanisms for the diversification of *Vitis* species in temperate North America in a changing climate.

Grape evolution

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grape team including Ze-Long Nie, Richard Hodel, Zhi-Yao Ma, Gabriel Johnson, Chen Ren, Ying Meng, Stefanie Ickert-Bond, Xiu-Qun Liu, Elizabeth Zimmer, and Jun Wen.

The grape genus *Vitis* has about 75 species constituting a charismatic component of the north temperate flora, with a few species also extending to the tropical zone. The grape genus is also sister to a lineage of tropical relatives from Central America. Hence the grape genus represents an attractive model to explore how temperate radiation occurred from its tropical origin and to track the diversification history of more than 50 million years since the geological epoch of the Eocene when the earth was relatively warm (i.e., the boreotropics).

The grape team applied various analyses ranging from phylogenetics, biogeography, and phylogenetic networks using extensive genomic data with an emphasis on the New World *Vitis* and its Eurasian relatives. The biogeographic inference and fossil evidence support that *Vitis* originated in North America and diverged from its closest sister group around 60 million years ago in the Paleocene geological epoch. The grape genus was widely distributed from North America to Europe during the Paleocene to the Eocene, followed by widespread extinction and survival of relict populations in the tropical New World. During the warming climate of the early to mid Miocene (20-15 million years ago), a *Vitis* ancestor migrated northward from the refugia with subsequent diversification across the North American region (see figure on the next page).

The grape research team also found strong evidence for different evolutionary signals encoded in different genes within both recent and ancient lineages of the New World *Vitis*. In other words, the different nuclear genes are telling different histories of the plant evolution, which signals hybridization and even introgression, with the latter as a type of more complex hybridization involving repeated backcrossing with one of the parents. Furthermore, the evolutionary tree inferred using the chloroplast genomes showed strong conflicts with the evolutionary tree inferred from the nuclear genomes, another common pattern as a result of hybridization and introgression. Extensive analyses based on genomic datasets hence strongly support the important role of wide occurrence of hybridization and introgression in driving the diversification of North American *Vitis* in the last 5-20 million years.

The study highlighted that hybridization potentially represents one of the most

***Vitis simpsonii* from coastal plains of eastern North America (Queen Anne County, Maryland). (photo by J. Wen)**

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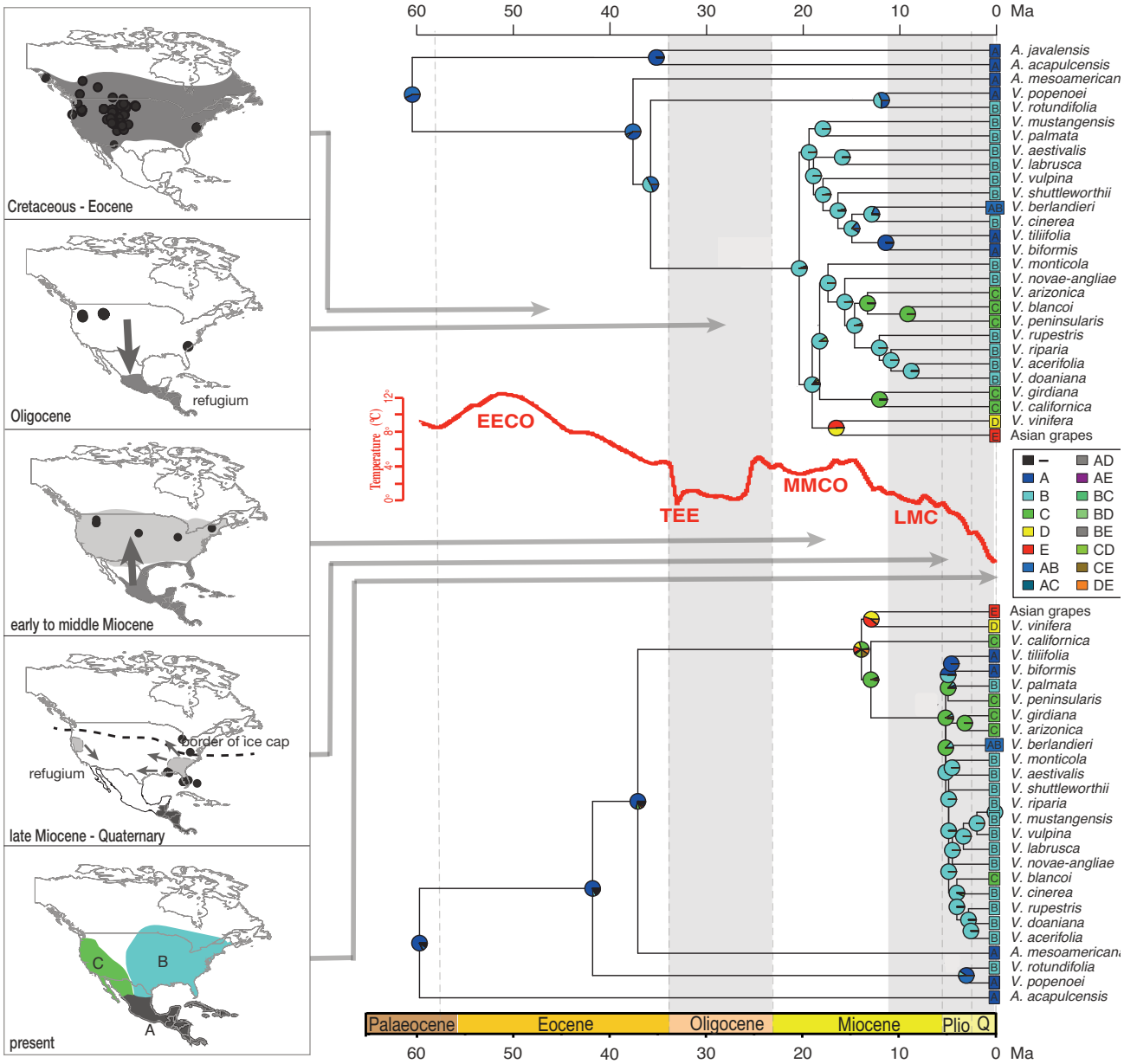
On the cover: *Vitis nesbittiana* from Xalapa, Veracruz, Mexico. (photo by J. Wen)

important mechanisms for the diversification of *Vitis* species in temperate North America and even the entire temperate Northern Hemisphere in a changing climate. The scenario reported in this study may be a common model of temperate diversification of flowering plants that adapted to the global climate cooling and fluctuation in the last 50 million years. The study also supports the hypothesis that modern temperate biomes originated and expanded in relatively recent times in Earth's history when global climate cooling intensified after the warming period of the late Eocene.

This study has important implications for our understanding of how the effects of past climatic changes on plant biogeography may impact the future responses of plants, including grapes, to ongoing severe climatic changes. The grape team led by Wen is now using the biogeographic and speciation history they learned on grapes to further advocate the importance on understanding the evolutionary history for classifying, conservation, and utilization of this important lineage of plants.



The spatio-temporal evolutionary history of New World *Vitis* based on the nuclear species tree (upper topology) assigning individuals to species group except for all the eastern Asian taxa assigned to one tip as well as chloroplast genomic data (lower topology). Maps on the left show fossil records (dots), boreotropical range (dark gray), and possible biogeographic distribution of the New World *Vitis* (light gray) in response to major shifts in Cenozoic climate (red curve). Abbreviations: EECO (Early Eocene Climatic Optima), TEE (Terminal Eocene Event), MMCO (Mid-Miocene Climatic Optimum), LMC (Late Miocene cooling), Plio (Pliocene), Q (Quaternary). Areas: A (Central America), B (eastern North America), C (western North America), D (Europe to western Asia), and E (eastern Asia).

Speakers announced for the 21st Smithsonian Botanical Symposium

The Smithsonian National Museum of Natural History Department of Botany, the United States Botanic Garden, and Smithsonian Gardens will hold the 21st Smithsonian Botanical Symposium, "Advancing Plant Conservation Through Horticulture," on 17 May 2024. The focus of the Symposium will be on conservation horticulture, the application of the technical knowledge and practical expertise of growing plants (horticulture) for the advancement of plant conservation. Conservation horticulture is critical in our time of rapid global change if we are to ensure the survival of imperiled plant species. Botanic gardens and conservation organizations around the world maintain diverse and wild-collected ex situ plant collections, care for plants of conservation concern in situ, provide plants for population augmentation and repopulation, and support conservation education and advocacy. Many plants that are extinct or facing extinction in the wild persist in cultivation through such efforts. The 21st Smithsonian Botanical Symposium will explore these topics and current research on the nexus of plant conservation and horticulture.

The following speakers are confirmed to give presentations followed by a panel discussion:

Jennifer Cruse-Sanders (State Botanical Garden of Georgia), "From dwarf sumac, *Rhus michauxii*, to turkey beard, *Xerophyllum asphodeloides* (and other species in between): How conservation horticulture has helped to preserve imperiled species in the southeastern U.S."

Colin Khoury (San Diego Botanic Garden), "Distributions, conservation assessments, and conservation action for crop wild relatives"

Carlos Magdalena (Royal Botanic Gardens Kew), "The many facets of botanical horticulture"

Abby Meyer (Botanic Gardens Conservation International). "Conservation horticulture capacity at botanic gardens"

Dustin Wolkis (National Tropical Botanical Garden), "Applied seed conservation biology to support seed banking"

The Symposium will be a hybrid event, with invited speakers giving afternoon presentations for both in-person and virtual guests in Baird Auditorium of the National Museum of Natural History, and a poster session and evening reception for in-person guests in the Conservatory of the U.S. Botanic Garden. Optional behind-the-scenes tours of the Smithsonian Gardens and the Joseph F. Cullman 3rd Library of Natural History will also be available in the morning before the symposium begins.

Registration and a call for poster abstracts will open on February 1, 2024. For more information, visit https://naturalhistory.si.edu/research/botany/news-and-highlights.

BOTANY FAMILY PICNIC 2023

Continuing a tradition that began in 2021, the Botany Family Picnic was held for a third time on 14 October at Carderock Recreation Area in Potomac, Maryland. Since many members of the department continue to telework during the week, the picnic gave Botany members and their families a chance to gather and build morale. As was the case in years prior, it was wonderful to be able to catch up, meet extended family members, laugh, and share stories of our research, discoveries, and travels. We also remembered to get a group photo!

GEO-TREES is launched at COP28

ForestGEO has recently launched the GEO-TREES consortium—the world's first ground-based, equitably developed forest biomass reference system, designed to make global satellite-based forest carbon assessments actionable. This unprecedented multi-network collaboration will use innovative technology, partnerships and training, broad sampling and long-term commitment, and open-access data to provide the groundwork for devising strategies to mitigate climate change.

The GEO-TREES project <https://geo-trees.org/> officially launched in December at the 28th Conference of the Parties to the United Nations Framework Convention on Climate Change (COP28). Leading up to the launch, the Smithsonian Tropical Research Institute (STRI) released a video series on social media in which STRI scientists explained the importance of the project and what they are set out to do. The motivation behind GEO-TREES is to determine how much carbon forests actually sequester. Models exist which use forest-imaging satellites to estimate how much carbon is stored in forests, but ground data has not been used to calibrate these systems. This is where GEO-TREES comes in – it is a network of forest plots and networks which will be collecting data in the field to calibrate and validate the models.

STRI's video series is available on social media at <https://twitter.com/stri_panama/status/1727359412774609265>, <https://twitter.com/stri_panama/status/1732473228294054177>, and <https://twitter.com/stri_panama/status/1732761055024251100>. A recording of the GEO-TREES launch at COP28 is at <https://www.youtube.com/watch?v=Tx0bfDsTThE&t=1s>, which features **Stuart Davies** (ForestGEO), Cristián Samper (Nature Solutions, Bezos Earth Fund), Adriane Esquivel Muelbert (University of Birmingham), Craig Hansen (World Resources Institute), and Frank Martin Seifert (European Space Agency). The panel was moderated by Ellen Stofan (Smithsonian) and Josh Tewksbury (Smithsonian Tropical Research Institute).

One of the largest trees on Barro Colorado Island in Panama. Tropical forests pull carbon dioxide out of the atmosphere where it causes global warming and store it as wood. But the amount of carbon stored varies depending on tree species, age, climate conditions and other factors. Verifiable estimates of carbon stored in forests are necessary to calculate carbon credits. (photo by Steve Paton)

ForestGEO hosts virtual seminar series

On the third Wednesday of every month, ForestGEO hosts a virtual Seminar Series which highlights ongoing research by scientists in the ForestGEO network. In November, Claire Fortunel and **Stuart Davies** gave presentations. Fortunel presented her lecture "Abiotic and biotic drivers of tree dynamics," during which she discussed how tree-based research approaches can greatly improve mechanistic understanding of community dynamics, and provided specific examples of what abiotic and biotic factors influence tree dynamics. Davies presented his lecture "GEO-TREES: Building a biomass reference system for the world's forests," during which he gave an overview of the GEO-TREES mission and emphasized multi-network collaboration to aid in the development of such a global forest biomass reference system.

If you are interested in recordings of past seminars <https://forestgeo.si.edu/seminar-series-past-speakers> or would like to participate in an upcoming virtual seminar, email ForestGEO Administrative Assistant Isabella Valli <valliie@si.edu>. To get reminders and announcements about upcoming seminars, sign up for the ForestGEO Listserv <https://forestgeo.si.edu/listserv-signup>.

ForestGEO
GLOBAL EARTH OBSERVATORY NETWORK

Learning the art of botanical illustration

Alice Tangerini presented a lecture and led a botanical illustration class at the Denver Botanic Gardens from October 10-16, 2023. Her lecture, "Botanical Illustration at the Museum," was presented to members of the Garden in person and virtually on Zoom. Along with the lecture, Tangerini displayed several of her botanical drawings showing the techniques used in both traditional and digital media and explained the reasons for choosing the different media.

Tangerini then taught a three-day class, Botanical Portraits in Layered Media, to 14 students at the Gardens using the Gardens' collections of *Helianthus annuus*, including living cut flowers and herbarium specimens, as subjects. She spent a day selecting flowering material from the Gardens that was also available as herbarium specimens that could be photocopied for the class.

The class media included a combination of graphite pencils designed for use on translucent drafting film where the class traced the photocopies to achieve a quicker rendition of the *Helianthus*. An underlying layer on film using opaque watercolor and colored pencil supplied the color to achieve a lifelike depiction of the subject. The class produced successful illustrations and the students discovered media that could be applied to other plant subjects. The Denver Botanic Gardens was an especially interesting place to visit at that time of year. It was decorated for Halloween and a fall festival held at the end of October.

Alice Tangerini (right) leading a botanical illustration class (bottom right) at the Denver Botanic Gardens in October 2023. Tangerini taught the three-day class to 14 students using the Gardens' collections of *Helianthus annuus*, including living cut flowers and herbarium specimens, as subjects. (photos courtesy of the School of Botanical Art and Illustration, Denver Botanic Gardens)

"Sunflower" by Brittany Hass (bottom left). (image courtesy of the artist)

Travel award recipients visit Smithsonian

Igor Azevedo, a post-doctoral researcher from Universidade Federal do Mato Grosso, Cuiabá, Brazil, is studying the taxonomy of Acanthaceae. He has been working on this family since the beginning of his undergraduate career, and now his research focuses on revising the taxonomy, phylogeny, and biogeography of members of Trichantherinae, a Neotropical subtribe with six genera and about 80 species distributed from the Amazon to Mexico. The U.S. National Herbarium houses a great number of collections of this group including more than half of its type specimens. Consulting the collection was essential to finish the first part of his taxonomic revision of the genus *Sanchezia*. During an October 2023 visit to the herbarium as a 2020 José Cuatrecasas Fellow, he was able to confirm at least 10 new species, which are now being prepared for publication. The correct identification of the collections of Trichantherinae species is also highly important for the next steps of his project, especially the biogeography, in which he will evaluate both the geographic distribution of the species and their evolution associated with the paleohistory of their habitats.

Maria Liris Barbosa de Silva, a Brazilian PhD student in Botany at Programa de Pós-Graduação em Botânica, da Universidade Estadual de Feira de Santana (PPGBOT-UEFS) is a 2023 José Cuatrecasas Fellow. Her thesis aims to produce a molecular phylogeny of the genus *Bidens* (Coreopsideae, Asteraceae) focusing on the pantropical clade and conduct a taxonomic study of Brazilian species within the genus. During her visit to the U.S. National Herbarium, she was able to analyze the morphology of specimens of *Bidens* from Africa, Central and South America, as well as the Pacific Islands, including type materials of *Bidens* species that occur in these areas. She acquired 19 samples of 14 species for DNA extraction, improving her sampling of the pantropical species. Her morphological analysis and the new DNA samples acquired will contribute to the overall understanding of the taxonomic and evolutionary relationships within the genus.

Florencia Dosil, the 2023 Robinson & Funk Fellow, is working on a systematic revision, phylogeny, and biogeography of the Neotropical species of *Adenostemma* (Eupatorieae, Asteraceae). She is a doctoral student from Museo de La Plata, Universidad Nacional de La Plata, Argentina, and she visited the herbarium from October to November.

Igor Azevedo (left) is a 2020 José Cuatrecasas Fellow studying the taxonomy of Trichantherinae (Acanthaceae). Maria Liris Barbosa de Silva (right) is a 2023 José Cuatrecasas Fellow studying the taxonomy of *Bidens* (Coreopsideae, Asteraceae). Both researchers visited the U.S. National Herbarium in the fall.

VISITORS

Zhiqiong Lan, Chengdu University of Traditional Chinese Medicine, China; *Alisma* (Alismataceae) and Sichuan medicinal plant diversity (3/1-12/22).

Lei Duan, South China Botanical Garden, Guangzhou, China; *Ormosia* (Fabaceae) (9/14/2023-2/14/2024).

Rafael Barbosa-Silva, Goeldi Museum, Brazil; Bonnetiaceae (9/25-10/2).

Carolina Guerreiro, Instituto de Botanica Darwinion, Argentina; Bambusoideae (Poaceae) (10/2-10/20).

Alison Colwell, University of California, Davis; *Cryptantha* (Boraginaceae) and *Poa* (Poaceae) (10/3).

Florencia Debora Dosil Hiriart, Museo de La Plata, Argentina; *Adenostemma* (Asteraceae) (10/9-11/30).

Robert Lawton, University of Alabama in Huntsville; Costa Rican cloud forest *Guarea* (Meliaceae) (10/11).

Allix Coon and **Rabi Musah**, University at Albany; Wood collection (10/16-10/20).

Marcos Bergmann Carlucci, Federal University of Parana, Brazil; General ecology and botany (10/18).

Diana Trujillo, Herbario Nacional de México (MEXU), Mexico; *Cercocarpus* (Rosaceae) (10/24-12/23).

Shiella Olimpos, University of North Carolina; Philippine *Saurauia* (Actinidiaceae) (10/29-11/17).

Maria Liris Barbosa de Silva, Universidade Federal de Alagoas, Brazil; Asteraceae (11/6-11/15).

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Visitors

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Talita Bellonzi, University of São Paulo, Brazil; Beslerieae and Napeantheae (Gesneriaceae) (11/13-11/17).

Nick Ruppel and six students, Randolph-Macon College; Tour of the herbarium and the fossil collection (11/20).

Giulia de Gennaro, Missouri Botanical Garden; Caribbean Lobelioideae and *Lobelia* sect. *Tylomium* (Campanulaceae) (11/27-11/30).

Mariela Nunez Florentin, Instituto de Botánica del Nordeste, Argentina; Spermacoceae (Rubiaceae) (11/27-11/30).

John Mitchell, New York Botanical Garden; Anacardiaceae (12/7-12/8).

Maria Anaya and **Leo Guzman**, Universidad de Guadalajara, Mexico; *Zea* and *Guadua* (Poaceae) (12/11-12/13).

Jana Harper, Vanderbilt University; Ethnobotany of Mackinac Island, Michigan (12/14).

Guy Nesom, Academy of Natural Sciences; Asteraceae (12/19-12/20).

Lina Han, South China Botanical Garden, Guangzhou, China; Fabaceae (12/23/2023-1/4/2024).

TRAVEL

Stuart Davies traveled to Dubai, United Arab Emirates (DATES) to participate at the 28th Conference of the Parties to the United Nations Framework Convention on Climate Change (COP28) and to speak on the panel, "From Ground to Space: The Future of Forest Carbon."

Alice Tangerini traveled to Denver, Colorado (10/10–10/16) as an invited speaker to give a lecture on botanical illustration and teach a class, Botanical Portraits in Layered Media, at the Denver Botanic Gardens.

Warren Wagner traveled to Kauai, Hawaii (12/2–12/10) to work in the National Tropical Botanical Garden herbarium studying Hawaiian species of *Cyrtandra* (Gesneriaceae), collect specimens in the field, and gather data from populations.

STAFF ACTIVITIES

Smithsonian Botany postdoctoral fellow, **Alicia Talavera**, shared research on North American grapes during a bilingual 'Expert Is In' session in the Hall of Mammals at the National Museum of Natural History on Friday, December 29. She aimed to convey these key messages to the visitors: (1) Natural history museums play a vital role in discovering new species, providing crucial information for understanding and protecting nature, and enhancing our crops and food; and (2) Technological advancements allow us to extract abundant information from specimens in museums. This essential information helps us understand grape diversity, and enables us to adapt and improve cultivars in response to new challenges like climate change, and for the conservation of nature.

Botany postdoctoral fellow, Alicia Talavera, shares research on grape diversity at an Expert Is In session in the Hall of Mammals, NMNH. (photo by Arthur H. Earle)

Jun Wen visited the production facility of the United States Botanic Garden on December 12 to check the *Tetrastigma* (Vitaceae) living collections. *Tetrastigma* species are host plants of parasitic *Rafflesia* (Rafflesiaceae), which have the largest flowers in the world.

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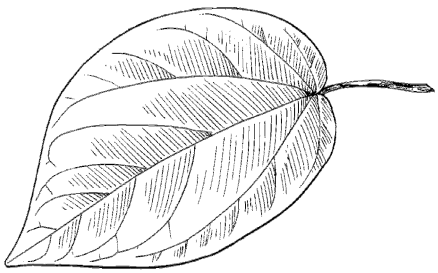
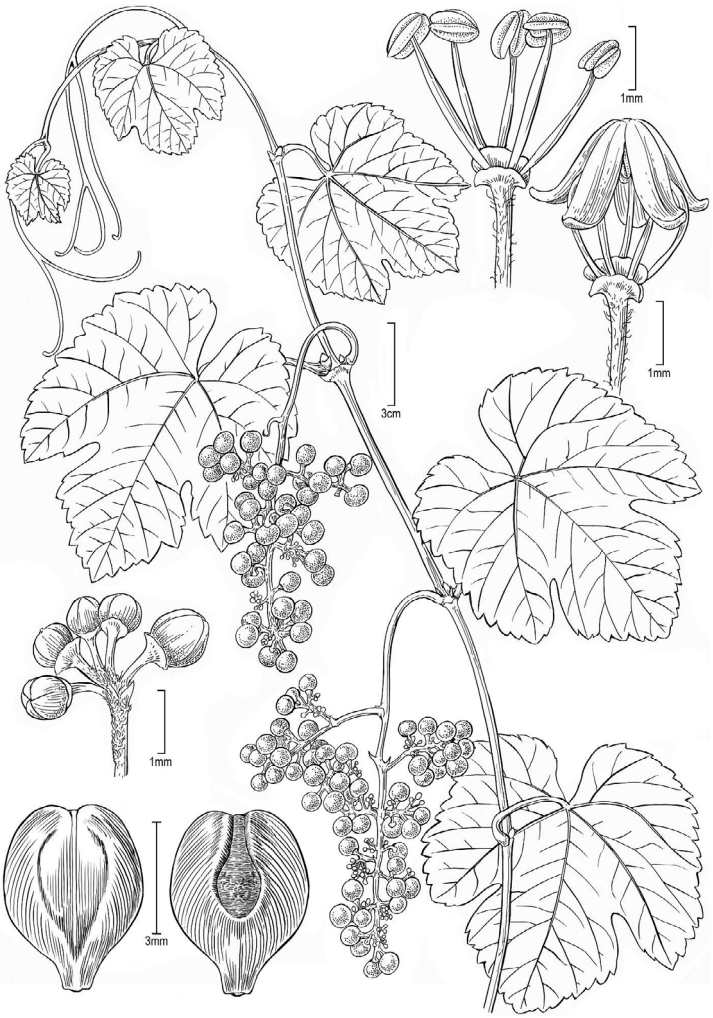


ART BY ALICE TANGERINI

Vitis californica Benth.

California grape is a unique western North American species native to central and northern California and southern Oregon. Recent genomic analyses suggest its ancient hybrid origin involves a maternal extinct parent species that may have given rise to the large speciose Eurasian clade of *Vitis*. The leaves of California grape turn beautiful orange and yellow in the fall and the purple fruits are edible but sour. Many populations of *V. californica* in the California wine region have hybridized with the wine grape *V. vinifera* as suggested by the featured article by Nie et al. (2023) in this issue of *The Plant Press*. The illustration displayed here was based on living cut collections brought by Jun Wen after a trip to Chico, California, in addition to herbarium specimens. One specimen was a collection by USDA illustrator F.A. Walpole from 1899. A note on the specimen mentioned a drawing done by Walpole. Alice Tangerini was able to locate the drawing at the Hunt Institute for Botanical Documentation, Carnegie Mellon University, and it was listed as an indefinite loan from the Smithsonian. A scan of the illustration appears on the Hunt website, and it supplied additional information about flower details. Tangerini's illustration appears in *Flora of North America North of Mexico*, Vol. 12 – *Magnoliophyta: Vitaceae to Garryaceae*.



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