Present Research on Patterns in Autumn Leaf Color

With good survey data on leaf color (and pigmentation) during leaf senescence from Massachusetts and Colorado, I contacted potential collaborators and came up with a team and a dramatically increased survey, both in totals of species and locations. The collaborators are seen in the photograph below. With the survey complete, and the write-up under the leadership of Niky Hughes and Mason Heberling, we have written up an abstract for a talk or poster at Botany 2022, meeting this July in Anchorage. After that, we'll prepare a manuscript and submit it for publication.

Authors and Team members of a Survey of Leaf Senescence in North American plant Communities.

David Lee (**1**, with wife Carol taken last October) first became interested in leaf color while working at the University of Malaya in the 1970s, and he expanded his interests to autumn foliage in Miami in the late 1990s. He worked at the Harvard Forest 1998 and 2004 on autumn foliage and collaborated with **John O'Keefe** (**2**, a scientist and educator there) making collections of plants in central Massachusetts while John continued his important longitudinal study of tree phenology at the Forest. **Niky Hughes** (**3**), pursuing Ph.D. research in leaf structure and function at Wake Forest University with Bill Smith, reached out to David in the mid-2000s. She had completed her M.S. thesis with **Howie Neufeld** (**4**) at Appalachian State University, a physiological plant ecologist with a long-standing interest in autumn colors, and she introduced Howie and David by organizing a field trip in the Blue Ridge in 2007. When the idea of doing a more geographically broad and extensive survey arose, they quickly became part of this project. David met **Cam Webb** (**5**) at the Arnold Arboretum in 2012, when he gave a talk on autumn color there. Cam, a tropical ecologist, later relocated to the University of Alaska Herbarium, and joined the project by making important collections in boreal forest and arctic tundra. As the survey and database expanded, we recognized the need for more skill in analyzing the data, and Howie suggested contacting **Mason Heberling** (**6**, Carnegie Museum of Natural History Herbarium); Mason also added important plant collections from an intermediate climate area near Pittsburg. With 12 sites for plant collections encompassing a range of values for climate, irradiance, soils, and nutrients, it was important to invite Niky's High Point University colleague, **Christian George** (**7**), whose spacial geographic skills helped in capturing more variables and in analyzing data. Finally, Mason recruited a newly minted University of Washington Ph.D. and fellow Washington State native, **Ben Lee** (**8**) for additional help in analyzing this large database.

Abstract Detail (Botany 2022, Anchorage)

Ecophysiology

Heberling, Mason [1], Hughes, Nicole M. [2], George, Christian O. [2], Lee, Ben [3], Neufeld, Howard [4], Webb, Campbell O [5], Lee, David W. [6].

Comparative analysis of autumn leaf coloration across North America.

Autumn leaf color has long fascinated biologists and the public. Though the biochemistry behind the phenomenon is relatively known, the adaptive value of autumn leaf color change remain poorly understood. Within a community, why do some species turn red and others do not? Across regions, why do some floras display more brilliantly colored foliage than others? Many hypotheses have been posited for the adaptive value of autumn leaf coloration, including coevolution with insects and photoprotection. However, these hypotheses are not mutually exclusive and may not be universal. Most comparative studies on autumn leaves use cultivated woody plants in botanical gardens. While useful, these studies have limitations by ignoring non-woody species, community context, and environmental variation. To quantify the species- and community-level patterns of autumn leaf coloration and link to hypotheses, we compiled a dataset from recent and previous fieldwork that includes 611 species and spans 13 sites from Alaska to Florida (768 total species by site observations). At each site, we surveyed vascular plant species with leaves present in autumn, scoring leaf color changing from green to red, yellow, or black. Tissue sections were also observed for the presence and intensity of anthocyanins in different anatomical layers. We also recorded habitat characteristics and life history characteristics for each species at each location. These observations were combined with environmental data for each site (soils, climate, irradiance). Across all sites, 52% of sampled species turned yellow during senescence, 46% turned red, and only 2% turned black (no color change with death by frost). This was highly variable across sites, ranging from 100% of autumn color changing species sampled at one site turning red (Alaska) to the other extreme with only 15% of all surveyed species turning red (Florida). Herbaceous and woody species were similarly likely to produce anthocyanins (44% vs. 46% respectively), indicating that herbaceous species are also be included in comparative studies of autumn leaf color. Long-lived herbs displayed higher levels of anthocyanins than annuals ($P<0.001$). Anthocyanins were higher in species that fruit during autumn ($P<0.01$). In support of the hypothesized photoprotective role of anthocyanins, red leaves were significantly associated with colder climates, shorter frost-free growing season, higher elevations, and higher latitude (northern sites). Against expectations, preliminary analysis of each variable individually suggest solar irradiance was negatively associated with red leaves and soil nitrogen was positively associated. However, these variables, along with climate variables, covary across latitude, thereby confounding potnetially causal patterns. This unique dataset provides new insights into understanding patterns and drivers of autumn leaf color.

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