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Evolution of flower, fruit, and seed defenses against herbivory and disease across the dogwoods, osiers and cornels (genus *Cornus*)

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Unlike most animals, plants are largely stuck in one place for the duration of their lives. This leaves individual plants vulnerable to changes in the local environment, and especially unable to escape from natural enemies like herbivores and pathogens. However, plants are not passive victims, and have evolved a wide array of defensive traits to resist attack, including a diverse chemical arsenal manufactured and stored in plant tissues. These chemical defenses can be highly effective at deterring feeding by a wide variety of insect and vertebrate herbivores as well as provide resistance to infection by bacterial or fungal pathogens through antimicrobial activity. Plant chemical defenses are vital to plant survival in the face of natural enemies, and coevolution between plants and these enemies is thought to be a major driver of the abundant plant diversity we see in nature[1].

Reproductive structures are unique in several ways – they directly determine plant fitness through the production of seeds and pollen, they are often ephemeral, and for animal-pollinated and dispersed species must balance attraction with defense. These qualities suggest several consequences for investment in plant defense. Structures so tightly linked to fitness would be expected to be heavily defended. More ephemeral structures would be expected to be less apparent to herbivores and less exposed to be pathogens, and thus less defended than more persistent structures. Flowers that are more attractive for the purposes of luring pollinators would also be expected to attract florivores, and thus more attractive flowers are expected to be more heavily defended. Fruits more palatable to dispersers with higher concentrations of sugars, starches, lipids, and protein would be expected to be simultaneously more defended against fruit-feeding insects and pathogens. After dispersal, more apparent (i.e. larger, more palatable) seeds would be expected to be more defended against seed predators.

Figure 1. Reproductive diversity in the genus *Cornus.* Top row (left to right): inflorescences of *C. florida*, *C. sericea*, and *C. mas*. Middle row: fruit of *C. florida*, *C. sericea*, and *C. mas.* Bottom row: fruit of *C. amomum, C. alternifolia,* and *C. kousa*

The present study examines the evolution of flower, fruit, and seed defenses across the diverse genus *Cornus* using the collections of the Arnold Arboretum. Contained within this living museum are

individuals representing 25 species native to North America, Europe, and Asia. At present, flowers and fruits have been collected from these diverse species as well as their flowering and fruiting phenology documented (Figure 2). Flower and fruit color was assessed across the ultraviolet and visible spectrum with reflectance spectrometry, and size and shape with digital calipers as well as tissue water content assessed. Floral and fruit tissue was then dried at 60°C in a forced-air drying oven and ground into a fine powder for ongoing analysis of nutritional quality (sugar, starch, protein, and lipid content) as well as abundance of chemical defenses (anthocyanins, flavonoids, phenolics, and tannins). Such phytochemical analyses are ongoing at present. Once obtained, the evolution of each of these traits will be statistically assessed using phylogenetic comparative methods and the most complete phylogeny of the genus available[2].

In addition, this project has allowed for the training of undergraduate student Corrinne Smith-Winterscheidt of Tufts University who participated in extensive training in field sampling and laboratory techniques. Corrinne collected the phenology data in Figure 2 and is currently analyzing floral tissue for chemical defenses. Once complete, this study will improve out understanding of basic plant defense evolution in relation to plant reproduction, and will also contribute to improved knowledge of the ecology and physiology of six native New England *Cornus* species, as well as several more species of horticultural importance. The data collected on flower and fruit nutrition and defense may also have utility for the horticultural and landscape use of native *Cornus* species, highlighting which have the best forage utility for native birds and which have traits predictive of resistance to insect pests and microbial pathogens.

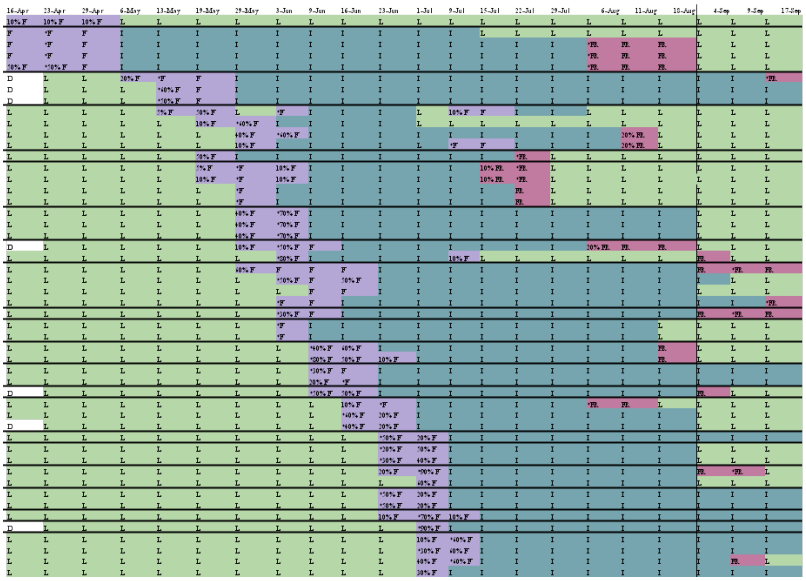

Figure 2. Diversity in phenology across the genus *Cornus* in the Arnold Arboretum: vegetative (green), flowering (purple), intermediate (blue), and fruiting (maroon), each week from April 16 through September 17, 2016. Note the variation in flowering and fruiting dates, as well as the length of the intermediate period.

References

[1] Futuyma DJ, Agrawal AA. 2009. Macroevolution and the biological diversity of plants and herbivores. *Proceedings of the National Academy of Sciences* 106, 18054-18061.

[2] Xiang Q-Y, Thomas DT, Zhang W, et al. 2006. Species Level Phylogeny of the Genus *Cornus* (Cornaceae) Based on Molecular and Morphological Evidence-Implications for Taxonomy and Tertiary Intercontinental Migration. *Taxon*, 55, 9-30.