Combined Proceedings IPPS 72:263-274. 2022.

Cornus (Dogwood) Breeding at Rutgers University

Thomas J. Molnar

Department of Plant Biology, The School of Environmental and Biological Sciences, Rutgers University, 59 Dudley Road, New Brunswick, New Jersey 08901, U.S.A.

thomas.molnar@rutgers.edu

Keywords: woody ornamental breeding, clonal propagation, budding, seedlings, novel cultivars

Summary

The Rutgers Woody Ornamental Breeding program began in 1960 and continues to this day. The breeding of big-bracted dogwoods has been a focal point of the program since Dr. Elwin Orton, the original breeder, pioneered the crossing of *Cornus florida* with the Asian *C. kousa*, which led to the successful Stellar® series of hybrid dogwoods. In 2006, the dogwood program transitioned over to new leadership and breeding efforts were expanded, building from a large collection of unique trees developed by Dr. Orton. In a fortunate turn of events, trees with vivid pink floral bracts were recovered in the new *kousa* and hybrid dogwood breeding populations leading to the 2015 release of *C. kousa* 'Rutpink' Scarlet Fire® dogwood. This manuscript describes some of the history of the dogwood program, followed by the lessons learned growing and selecting dogwoods at Rutgers for 15 years and what comes next after Scarlet Fire® dogwood.

INTRODUCTION

Dr. Elwin Orton was hired in 1960 to develop a Woody Ornamental Breeding Program at Rutgers University located in New Brunswick, NJ. A summary of his work is described in Molnar and Capik (2013). In brief, for the first 10 years his primary focus was breeding American holly (*Ilex opaca*) for the holiday cut-branch market. The goal was to combine the glossy leaves and beautiful berry displays of English holly (*I. aquifolium*) with the cold hardiness of native *I. opaca*. While the crossing of the two species proved unfruitful, it did lead to the development and release of several excellent *I. opaca* cultivars such as 'Jersey Princess' and 'Jersey Knight'. The American holly project later evolved into a program to develop a variety of unique landscape plants within the *Ilex* genus. Interspecific hybridization was a core component of the program as Dr. Orton enjoyed crossing and intercrossing a number of different holly species. The success of the program is exemplified by the release of *Ilex* × 'Rutzan' Red Beauty® holly, a cross of *I.* × *meserveae* and *I. pernyi* that is known for its deer browse tolerance, semi-compact form, and excellent leaf color and berry display.

Dr. Orton began his work with big-bracted dogwoods (*Cornus* sp.) in 1970 where his passion for interspecific hybridization continued. He pioneered crossing the eastern U.S. native *C. florida* with the Asian *C. kousa* to develop a series of hybrid cultivars released in the early 1990s and marketed under the Stellar Series® trademark name (Orton, 1993). The most widely grown cultivar from this series is 'Rutgan' Stellar Pink® dogwood, known for its vigorous growth, disease resistance, and abundance of blush-pink blooms. Note that this hybrid combination was given the formal species name *C.* × *rutgersensis* to help clear up nomenclature confusion in the nursery trade (Mattera et al., 2015). Dr. Orton also used the Pacific Northwest native *C. nuttallii* in his hybridization program with *C. kousa*. From this combination of species, 'KN30-8' Venus® dogwood was developed, a plant exhibiting excellent dark green foliage free of disease, with the largest floral bracts of any known dogwood. Venus® dogwood is thought by many to be his crowning breeding achievement (**Fig.1**) (Orton and Molnar, 2005; Eberts, 2011). Note that the hybrid cross between *C. kousa* and *C. nuttallii* was given the formal species name *C.* × *elwinortonii* in honor of Dr. Orton's breeding legacy (Mattera et al., 2015).

Figure 1. Dr. Elwin Orton and *Cornus* × *elwinortonii* 'KN30-8' Venus® dogwood in May 2014.

Continuing Dogwood Breeding Efforts

In 2006, the woody ornamental breeding program began its transition to new leadership although Dr. Orton remained in an active role for several years even after his retirement in 2008. It was decided that hybrid dogwoods would be the primary focus of the program going forward, but with a targeted goal of developing hybrid and kousa cultivars with dark pink or red floral bracts similar to those exhibited by *C. florida* forma *rubra*. Obtaining this color trait was a goal of Dr. Orton's since the program's inception in 1970. However, despite dozens of controlled crosses aimed at enhancing color and 1000s of seedlings grown to maturity, he was not able to recover color at the level he desired. In the end, his best pink-bracted plants only displayed minor improvements over existing pink kousas in the nursery trade such as 'Satomi' (**Fig. 2**). 'KN144-2' Rosy Teacups® dogwood is a great example. It is a beautiful tree with unique, large blooms, but the pink color is not significantly different than what was already available in the nursery trade (**Fig. 3**). Thus, the question remained of how to enhance bract color in the hybrid dogwoods.

Figure 2. Floral bracts of *Cornus* × *elwinortonii* 'KN30-8' Venus® dogwood next to blooms of *C. kousa* 'Satomi'. Photo credit Wolfgang Eberts.

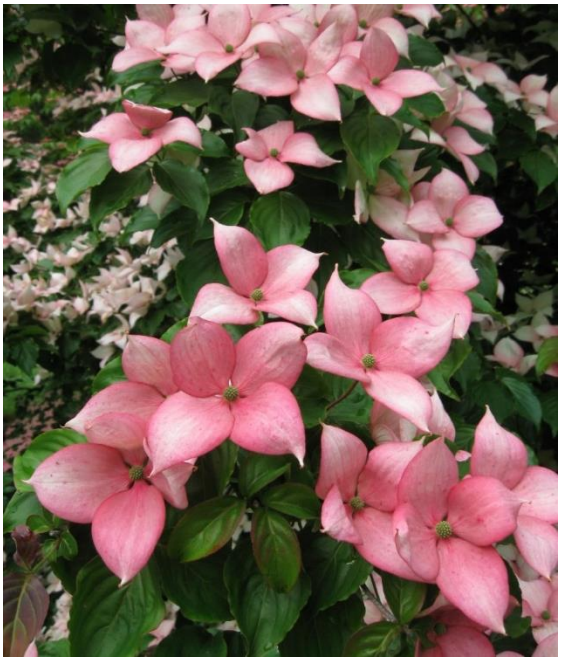

Figure 3. Floral display of *Cornus* × *elwinortonii* 'KN144-1' Rosy Teacups® dogwood.

Knowing that dogwoods are highly self-incompatible, it was decided that we should grow out a large population of open-pollinated trees from Dr. Orton's collection of elite breeding selections. The collection consisted of a group of about 50 trees planted in a private location isolated from other dogwoods. Each tree was special in one or more attributes and collectively represented decades of breeding and selection at Rutgers. Most were fertile advanced generation interspecific hybrids; some had blush pink and light pink blooms, while others were white in color. Over the next four years, open pollinated seeds were collected from nearly all the trees in the block; seeds were germinated and over 3,000 seedlings grown to maturity. As each tree was genetically unique, the hope was we might recover a new color combination and/or other valuable traits in the offspring that would help move breeding efforts forward (Molnar, 2017).

To our great surprise, this open-pollinated breeding approach worked—in 2012, 6 years after the project was started, we finally recovered several trees with exceptionally dark-pink bract color! While only a few out of the 3,000 grown had this improved color, we knew it was something special based on the intensity of the pigment and how the bracts glowed in the landscape at a distance. They were unlike any dogwoods we, Dr. Orton included, had ever seen before! One of the trees stood out clearly from the pack based on its vivid pink, almost fuchsia bract color, as well as its fantastic number of blooms at a young age, overall tree health, and tree vigor. We propagated it through budding in 2012 and after only three more years of evaluation decided to file a US plant patent application and release it to the nursery industry.

The tree was named *C. kousa* 'Rutpink' Scarlet Fire® dogwood in honor of the Rutgers mascot the Scarlet Knight combined with how the blooms glowed like "pink fire' in the landscape on a sunny day (**Fig. 4**; Molnar et al., 2017; PP 28,311).

Figure 4. *Cornus kousa* 'Rutpink' Scarlet Fire® dogwood showing bright pink bloom display from a distance. Picture taken at Rutgers University in May 2020.

Note that in our excitement over the tree we also initiated it in tissue culture (micropropagation), which allowed us to plant a stock block of nearly 50 trees prior to its release. These stock trees then allowed for the distribution of a large amount of bud wood early on to help increase numbers for commercial propagation and sale in a short period of time (for a tree species). We were also fortunate that the propagated trees grew quickly in nursery production, had a well-branched habit with a strong central leader, and continued to bloom heavily at a young age (a trait seemingly absent in the prior Stellar Series® releases). These traits, in addition to its bloom color, supported its selection as a Gold Medal Plant from the Pennsylvania Horticultural Society in 2022,

only 10 years after the original seedling first bloomed! These traits also set the bar very high for any subsequent releases from the Rutgers dogwood program.

Next Steps After Scarlet Fire® Dogwood

Two questions quickly arose: is this new dark pink floral bract color heritable? Can we use it in subsequent breeding? To investigate, starting in 2013 we crossed our few dark-pink bracted trees with each other and with additional trees in the program to grow out new breeding populations. We also culled the less desirable trees from our large seedling nurseries as part of the selection process and in doing so created new "crossing blocks" where the remaining trees (select trees that showed interesting breeding value) intercrossed naturally, and from which we grew additional open-pollinated seedlings. We continued this approach for several years, building up a new population of over 3,000 "next generation" trees for evaluation.

The first group of these trees bloomed in 2017 and many more in 2018. Again, we were blown away by what we saw! The dark pink bract color was indeed heritable, and we recovered many trees exhibiting a range of colors from blush pink to vivid bright pink all the way to pinkish purple (**Fig. 5**). We also observed significant variation in floral bract shape, size, number, and bloom phenology (timing), as well as tree growth habit, tree vigor, and leaf color. We now had literally hundreds of new trees with exciting bloom colors to select from and 1000s of younger trees waiting to flower in our fields. The questions now became: how do we most effectively and efficiently narrow our large pool of new trees down to a manageable level of superior individuals? With all this variation beyond just floral bract color, what tree types would be of the greatest value to the nursery and landscape industry? Answering these questions is still a work in progress.

Figure 5. Young hybrid *Cornus* breeding selection at Rutgers University exhibiting floral bracts with unique hues of dark pinkish purple.

WHAT HAVE WE LEARNED AFTER 15 YEARS OF GROWING DOGWOODS?

To date, we have grown more than 20,000 seedling dogwood trees (planted about 1,500 per year) of which over 10,000 have bloomed and been evaluated (and most cut down). A small percentage of these trees have been propagated for replicated trials and these and others have been used for further breeding. In 2022, we observed the first blooms on seedling trees that are two generation removed from Scarlet Fire®; in other words, grandchildren of Scarlet Fire®

and its cohorts! From these breeding and selection efforts we have identified a number of very promising trees, some of which are expected to be released as cultivars in the near future (and whose details we cannot disclose at this time); we are still deliberating on which specific trees to move ahead with. Further, along the way we have learned a lot about the dogwood breeding process and continue to refine our objectives and approach to developing improved trees. Following the motto of the IPPS "To Seek and To Share", we describe some of what we have learned below.

1. For greater impact, new cultivars should be easily differentiated from those already in the nursery trade. This is an obvious statement but one not always followed by plant breeders. To date, Scarlet Fire® dogwood continues to increase in popularity and numbers of trees sold each year which we appreciate as royalties returned from tree sales help support further breeding efforts. We have made it our goal that new releases from the program should be easily differentiated from Scarlet Fire® dogwood to help expand the market for new dogwoods instead of cutting into already existing sales with lookalike trees, e.g., dogwoods with floral blooms that are only marginally different (**Fig. 6**). We envision releasing a series of dogwood cultivars with unique traits that complement one another in the landscape, creating a desire to plant not just one specimen dogwood tree in a single location but a group of different cultivars planted together for added appeal.

Figure 6. *Cornus kousa* 'Rutpink' Scarlet Fire® dogwood on the left and its "lookalike", next generation seedling selection on right. They exhibit very similar bloom traits and precocious blooming habits, although with a slightly different shade of pink.

Following this logic, our breeding and selection goals are targeted on trees with unique attributes including (but not limited to) bract color and shape, growth habit, and time of bloom display. One example includes trees that exhibit novel floral bracts, such as double bracts or those that are highly dissected (**Figs. 7 and 8**) which can be combined with different shades of color spanning white, blush pink to vivid pink or nearly red. They can also differ considerably in leaf color, especially during phases of rapid growth in the spring (**Fig. 9**).

Figure 7. Novel double bract trait that appears in a small percentage of hybrid *Cornus* breeding selections.

Figure 8. Novel dissected floral bract trait that appears in a very small proportion of dogwood breeding selections.

Figure 9. Two-year-old field of hybrid *Cornus* seedlings showing a range of leaf colors from pale green to dark green to reddish orange to purplish red.

2. Precocious trees (those that bloom heavy at a young age) have added landscape appeal. Again, an obvious statement but one that presents some breeding hurdles when selection on trees has generally been done once they enter their mature blooming phase. Most kousa and hybrid dogwood trees look gorgeous once they are old and heavy blooming; their branches tend to extend far from the trunk and lean over to display abundant blooms which sit as rafts of color atop the leaf canopy. This example contrasts with most young trees that tend to grow vigorous, upright shoots that hold the blooms pointed toward the sky; they also tend to have fewer blooms per branch area which reduces their impact in the landscape. A breeding challenge arises under this scenario as mature plant phenotypes take a very long time to observe (slows the breeding cycle). Further, they are not always a reflection on how propagated plants respond as young trees in the nursery and the subsequent early "juvenile" years in the landscape. This early phase of tree growth is important as homeowners and other land managers may lack the patience to wait for their trees to grow for a decade before they have a notable display of blooms. Note that the Stellar Series® hybrids have received criticism along these lines. They are known to be spectacular mature specimens but may take 8-10 years or longer before they bloom heavily in the landscape.

Fortunately, within our breeding populations we have found trees that exhibit precocity; in other words, they bloom heavy at a young age. And in most cases, we have found this precocious blooming trait is carried over to propagated plants (budded trees tend to also bloom heavy at a young age). This has also been observed to be a heritable trait, where precocious blooming trees tend to have a higher proportion of precocious blooming offspring. Thus, we can target precocious blooming in our breeding and selection efforts.

In our current breeding nurseries, 15-20% of the seedlings bloom in their 4th growing season from germination. We start "selection" this year through a process of elimination where we immediately remove any trees whose floral bracts do not meet

our minimum criteria for color, shape, display habit, and/or size. The next year (year 5), about 75% of the total population blooms. We continue selection by the process of elimination and cull trees based on color expression as well as bract shape, bloom density, tree growth habit, and leaf quality. Selection continues throughout the bloom period taking into consideration response to high temperature fluctuations where there is significant variation in response per tree (some trees lose color once temperatures reach over 90° F [32° C]). Note that trees that do not bloom in year 5, unless they stand out for some other unique trait, are generally culled from our populations. This helps keep our focus on those with the propensity to bloom as young trees.

In year 6, the remaining trees are evaluated once again. To avoid elimination this year, they must not only have superior bloom and other traits, but they must now bloom heavy (>100 flower heads) and blooms must not be hidden behind leaves or positioned as such where they are showy only from above. Now that the breeding nurseries have fewer trees, sight paths are open. We take a step back and judge them for their landscape appeal at a distance. Only those rare trees that are unique in bloom traits and other attributes while also being visually striking at landscape level survive the selection process. The top selections in each age cohort will then be clonally propagated for replicated evaluation (those chosen for propagation are generally less than 2% of the starting population).

Once propagated, trees are field planted and evaluated alongside Scarlet Fire® and other cultivars of a similar planting age. Evaluation continues for the next 5 years. Only those breeding selections that develop into attractive, heavy blooming trees at an early age are considered for release. Some breeding selections will bloom their first growing season, which adds to their likelihood for release. Those that take more than 3 years to bloom heavy as propagated trees are considered less interesting and may be removed from the list.

3. Pruning breeding populations like propagation nurseries aids selections efforts. Early on, we thought it would be best to grow our seedling trees un-pruned to observe their natural growth habits. This led to many trees with multiple leaders, wide crowns, and unruly branching. While providing insight on the trees' natural habits, this approach was not only harder to manage at our research farm due to messy, diverse trees, but we later realized it was also not reflective of how the trees are grown in commercial nursery production. And subsequently not how they will be grown later in the landscape.

Dogwood cultivars are typically propagated through chip budding low to the ground on seedling understock. The developing scion is carefully managed as a single trunk tree that has its branches removed from the bottom 2 to 3 feet or more from the crown. Under this production system, it is important that a tree has a strong central leader, good apical dominance, and sufficient branching to make an attractive and full tree canopy at a young age. The tree should also have good branch angles (not too wide and not too narrow unless a fastigiate form is desired) and tend not to be "leggy", i.e., have very long internodes which show a lot of stems and not a lot of branches and foliage, especially on young rapidly growing trees.

Earlier in our breeding program, when seedling trees were not pruned, it was

easy to overlook those trees that had weak apical dominance (multiple competing leaders) and poor branching, as we focused primarily on bloom traits and not growth structure. Thus, a number of plants we selected from the earlier populations of trees as superior for bloom traits ultimately performed poorly under propagation. Once budded, they were found to develop crooked trunks, many competing leaders with weak crotch angles, and/or unappealing leggy growth with reduced branching. Note that discarding a tree from the potential release list only after we learn of its poor propagation performance (a three-year process) wastes considerable time and resources.

Today, we use a different approach. We now prune all our seedlings (~1,500 trees planted per year) to single trunks and lift the bottom 2-3 feet of their branches in years 2 and 3, more similar to how budded trees are managed. Although labor intensive, this pruning is very helpful for weed management in our nurseries while allowing us to better examine trees for their single trunk growth habit. We now eliminate those with poor apical dominance, weak branching, and leggy growth that could have been masked in the presence of multiple leaders found in unpruned seedling trees.

We are fortunate that dogwood growth habit appears to be under strong genetic control (a seedling with a strong central leader tends to maintain this trait once clonally propagated). We have found that our recent trees selected from our pruned breeding nurseries generally perform very well as budded trees (only those that look good as pruned seedling trees make it to the next stage of evaluation).

4. Bloom phenology is an important selection tool. Most of the trees in our program, despite their interspecific hybrid background, tend to look much like kousa dogwoods and bloom during the time of kousa dogwoods (late May into June in New Jersey). However, there is variation in bloom time (date of peak bloom size each year) as well as how fast blooms expand to the point where they are showy in the landscape. As an example, Scarlet Fire® dogwood starts out later than some other trees and has small bracts that take several weeks to become showy (**Fig. 10**). Trees that expand their bracts quickly can have a longer display period in the landscape.

Figure 10. *Cornus kousa* ‘Rutpink’ Scarlet Fire® dogwood blooms in early May. They start off small and take several weeks to expand to full size.

Further, the pigment group responsible for pink and red colors in dogwood bracts is primarily the anthocyanins. Expression of anthocyanins can be affected by temperature, generally with expression of darker colors when air temperatures are

cooler and lighter when it becomes hot. We find in central New Jersey the spring temperatures can fluctuate considerably. However, the later we get into May the more likely we will see a stretch of days with air temperatures over 95°F (35°C). This is the temperature when we tend to see pink colors begin to fade in many of our "dark-pink" dogwood selections including Scarlet Fire® dogwood. However, we found that if a tree has sized up its bracts before the high temperatures occur, they tend to better maintain the color through the heat without a lot of visible degradation. This contrasts with those that still have small, developing bracts which are more affected by the heat and may never reach their peak color if it gets too hot during the bract expansion period.

Thus, since we now have large, diverse breeding populations, we can select for dark-pink colored trees whose bracts size up earlier than the average (7-10 days prior to Scarlet Fire®). We have found that these trees tend to maintain pink color longer during the bloom season and into hotter weather. They might not be inherently darker pink regarding concentration of pigment and color of blooms in cooler spring seasons, but by sizing up earlier they can have more intense colors (purplish red colors), and then a subsequently a longer display of that color. In this case, early phenology of bloom gives a visible boost in color related to temperatures during which the peak bloom size and coloration occurs.

CONCLUSIONS

Today, our breeding program and its successes stands on the shoulders of Dr. Elwin Orton and his decades of dogwood breeding work at Rutgers University. We have pedigrees in our newest dogwood selections that reach back to 1970 and span seven generations of breeding and selection. Based on Dr. Orton's germplasm in combination with help from insect pollinators and some good luck, we recovered a breakthrough dark-pink bract color in hybrid and kousa-type dogwoods that led to the release of Scarlet Fire® dogwood. Fortunately, this dark pink color is heritable, and we have used it in breeding to grow large populations of plants from which to select new trees several of which should be forthcoming as new cultivar release in the near future. Along the way, we have fine-tuned our breeding approach and learned more about dogwood trees. This platform allows us to share some of that knowledge, which we hope will be of value to others working in ornamental tree breeding and those interested in the path taken to develop new dogwoods at Rutgers University.

LITERATURE CITED

Eberts, W. (2011). How *Cornus* 'KN30-8', Venus® hybrid dogwood made it to Europe. Comb Proc. Intel. Plant Prop. Soc. *61*:366-371.

Mattera, R., Molnar, T., and Struwe, L. (2015). *Cornus* × *elwinortonii* and *Cornus* × *rutgersensis* (Cornaceae), new names for two artificially produced hybrids of big-bracted dogwoods. PhytoKeys *55*:93–111 https://doi.org/10.3897/phytokeys.55.9112

Molnar, T.J. and Capik, J.M. (2013). The Rutgers University woody ornamentals breeding program: past, present, and future. Acta Hort. *990*:271–280.

Molnar, T.J., Muehlbauer, M., Wadl, P. and Capik, J. (2017). *Cornus kousa* 'Rutpink' (Scarlet Fire®) dogwood. HortSci. 52:1438–1442. 9.

Molnar, T.J. (2017). Going nuts: continuing a 40-year-old woody ornamental breeding program. Acta Hort *1174*:305-312 (Comb Proc. Intel. Plant Prop. Soc.)

Orton, E.R. (1993). New large-bracted dogwoods from Rutgers University. Comb. Proc. Int. Plant Prop. Soc. *43*:51-54.

Orton, E.R. and Molnar, T.J. (2005). Exciting developments in the world of *Cornus*. Comb. Proc. Int. Plant Prop. Soc. *55*:322-325.