Going nuts: continuing a 40-year-old woody ornamental breeding program©

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INTRODUCTION

The Rutgers University Woody Ornamental Breeding Program began in 1960 under the direction of Dr. Elwin Orton. He was initially charged to develop a holly (*Ilex* species) breeding program with the ambitious goal of crossing *I. opaca*, our native eastern holly, with the English holly, *I. aquifolium*. The main premise was to develop an improved plant for the holiday cut branch market that expressed the excellent glossy foliage and berry display found on the English holly combined with the cold hardiness and wide adaptation of the American species. Dr. Orton, a scientist trained in classical corn genetics at the University of Wisconsin, accepted this responsibility and put in a tremendous effort to achieve this goal. Unfortunately, however, after over a decade of tedious work, Dr. Orton abandoned the *I. opaca* × *I. aquifolium* project, largely due to genetic incompatibilities between the two species. Fortunately, during this time he also did selection and breeding work within *I. opaca* alone, which yielded several cultivar releases. These include *I. opaca* 'Jersey Princess', 'Jersey Knight', 'Dan Fenton', Jersey Delight', and most recently 'Portia Orton'. All are female except 'Jersey Knight', and several have become well known in the nursery and landscape trade especially noted for their excellent dark green, glossy foliage. Besides *I. opaca*, Dr. Orton also worked with Japanese holly. *Ilex crenata* 'Beehive' was his best known release—a plant selected from more than 21,000 seedlings derived from crossing *I. crenata* 'Convexa' × *I. crenata* 'Stokes'. 'Beehive' was selected for its mite resistance, cold hardiness, and compact form. In addition, he also released several dwarf forms of the species—'Green Dragon' and 'Dwarf Pagoda' were the most widely known (Galle, 1997).

HYBRID HOLLIES

In the late 1960s, Dr. Orton began a program of interspecific hybridization among a number of different *Ilex* species to generate novel cultivars. One approach was the crossing of *I. verticillata* (winterberry holly) with *I. serrata* (Japanese winterberry) at a time when the deciduous hollies were not as widely used in the landscape. With this cross, he hoped to reduce the vigor of *I. verticillata* and, conversely, to increase the size of the more diminutive *I. serrata*—while improving fall leaf color, berry color and number, and the persistence of the berries into the winter. This goal was achieved with the release of *Ilex* 'Harvest Red' and 'Autumn Glow', as well as a companion hybrid male pollinizer named 'Raritan Chief'. These three cultivars are still commercially available today.

Another noteworthy interspecific hybrid released by Dr. Orton was *I.* 'Rock Garden', an extreme dwarf plant of unique form with attractive foliage and large red fruit. It resulted from a cross of a seedling of *I. aquifolium* × *I. pernyi* with a seedling of *I. integra* × *I. pernyi*. 'Rock Garden', released in 1984, is considered to be the first dwarf-statured plant with a "holly-type" leaf introduced to commerce (Galle, 1997). Another more recent hybrid plant worthy of mention is *I.* × 'Rutzan' Red Beauty® holly ([*I. rugosa* × *I. aquifolium*] × *I. pernyi*), which was released in 2003. It has small, dark-green, spiny leaves similar to the Meserve hollies (*I.* × *meserveae*), but is single stemmed rather than shrub-like, requiring very little pruning. Plus, it bears heavy crops of large, red fruit—and has proven resistant to deer browse in tests across many regions.

A final plant to mention is *I.* × 'Winter Bounty', which is an *I. ciliospinosa* × *I. latifolia* hybrid with very unique plant form, long spineless leaves, and extremely heavy berry display

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(Figure 1). To date, this novel, publically-released plant has not yet found its place in the landscape—hindered somewhat by its palatability to deer. Hopefully, its unique beauty will encourage the industry to examine it in the future (Figure 1). A much more complete description of the various *Ilex* cultivars released from Rutgers can be found in Molnar and Capik (2013) and Galle (1997).

Figure 1. *Ilex* 'Winter Bounty' holly. Public release from Rutgers University.

While no additional *Ilex* crosses are being made at this time, we have preserved a core collection of genetic resources that were assembled and developed over more than four decades. We have narrowed the collection to less than 400 accessions and will continue to examine them to identify individuals that may show merit for release or breeding in the future.

HYBRID DOGWOODS

Besides hollies, Dr. Orton was well-known for his work with hybrid dogwoods (*Cornus* spp.). While he released several pure *C. florida* cultivars ('Rutman', Wonder Berry® flowering dogwood; 'Rutnam', Red Beauty® flowering dogwood; and 'D-383-22', Red Pygmy® flowering dogwood), he is credited with being the first person to hybridize *C. florida* and *C. kousa* (*C.* × *rutgersensis*). From his work started in the 1970s, Dr. Orton released a series of excellent F_1 hybrid plants in the early 1990s; the most popular was 'Rutgan', Stellar Pink® dogwood, a vigorous, upright plant with light-pink floral bracts. Other F_1 introductions from this time period include 'Rutban', Aurora® dogwood; 'Rutcan', Constellation® dogwood; 'Rutlan', Ruth Ellen® dogwood; 'Rutdan', Celestial® dogwood; and 'Rutfan', Stardust® dogwood, all of which have white floral bracts but vary in the shape of the bracts and their growth habits. 'KF1-1', Saturn™ dogwood, while from crosses made during the same time as the original set of releases, was not introduced until 2007. To many of us who have seen the original tree in bloom, it may be the best of all the F_1 hybrids.

In 2011, 'KF111-1', Hyperion® dogwood, an extremely vigorous and showy backcross to *C. kousa*, was released, which is slowly becoming known in the nursery trade. Over this time period, Dr. Orton also worked with *C. nuttallii*, the Pacific Coast dogwood, and released the hybrids 'KN4-43', Starlight® (*C. kousa* × *C. nuttallii* F_1); 'KN30-8', Venus® dogwood (a backcross to *C. kousa* known for its giant white bracts), and Rosy Teacups® dogwood PP 26211 (an advanced generation hybrid with medium-pink colored bracts *C. kousa* × *C. nutallii*). When comparing these plants to the Stellar® hybrids derived from *C. florida*, an increase in bract size, striking white bract colors, excellent dark green leaf color, and resistance to leaf curling during drought appear to be some of the strongest contribution of the *C. nuttallii* parents. See Orton (1985, 1993), Orton and Molnar (2005), and Molnar and

Capik (2013) for additional details on the Rutgers dogwood releases.

TAKING THE REINS: IT'S TIME TO GO NUTS!

I officially became responsible for the ornamental breeding program in 2008; however, in 2006 I began working closely with Dr. Orton to prepare for the likely transition. I examined the existing program in detail and tried to find a place where I could make a valuable contribution to the breeding of dogwoods in a program that has been ongoing for decades and already very successful.

Does the world really need a new white-bracted hybrid dogwood?

The breeding objective that stood out was the development of novel kousa and hybrid dogwoods with dark pink (and possibly red) bracts similar in color to those found on *C. florida* 'Cherokee Brave', 'Red Pygmy', or forma *rubra*. Dr. Orton had been working on this goal since the very beginning of the dogwood program in the 1970s (Orton, 1985; Orton pers. commun.)—yet he was not satisfied. The challenge (or problem) presented to me was how to realistically build on his previous efforts. Dr. Orton had performed thousands of hand crosses over several decades with many different combinations of pink kousa and hybrid dogwoods—and was not able to reach a bract color level substantially better than with *C. kousa* 'Satomi' or 'Rosabella'. He was able to get more consistent color expression and increased numbers of flower heads, but not the depth of dark pink color necessary to claim it as a "true" pink bracted kousa. Note: in New Jersey 'Satomi' tends to only be pale to light pink in most years. Many of the pink plants he selected from his crosses over the years seemed to have reduced vigor and poor growth habits. Thus, when taking over the program I did not know exactly where to begin in terms of which plants to cross or what new germplasm to acquire.

I decided to take a more haphazard approach. Since dogwoods are self-incompatible, we could generate tons of diversity and variation to select upon by growing out large open-pollinated (OP) populations. Dr. Orton had assembled an excellent germplasm collection for me to work with that included his best selections with pink floral bracts and, most notably, a number of rare fertile interspecific hybrid offspring (most are sterile). Over the decades, he created one of the world's most unique big-bracted dogwood crossing blocks with contributions from *C. florida*, *C. kousa*, and *C. nuttallii* (albeit in a variety of genetic combinations).

To start the next chapter in the Rutgers dogwood breeding program, my research technician John Capik and I systematically collected OP seed off of almost every plant in the collection and grew out large seedling populations (over 3,000 trees). We had no grand expectations on what we would find, but knew that we would see a lot of segregation of traits and maybe could get lucky with a unique combination of genes. Regardless, I knew that the process would teach us a lot about dogwoods and dogwood selection as we raised them and watched them grow to maturity.

By 2010, many of the trees from the first seed collection effort began to flower. There were lots of very beautiful white-bracted dogwoods, including hybrids and pure kousa types (hard to determine exactly what they are since pollen parents are unknown), and many light pink-bracted plants similar to what Dr. Orton had selected in the past. These trees promptly got cut down. What we didn't expect is that we would also recover some excellent, never-before-seen, dark pink bracted forms including a variety of shapes, sizes, and shades of pink color (Figure 2). In addition, numerous trees had good health and vigor, breaking through what Dr. Orton would have claimed was linkage or genetic drag (or inbreeding depression) associated with breeding with genes for pink color in dogwoods coming from a narrow genetic base. The most surprising finding was that many of the darkest pink seedlings came from mother plants that were only blush pink in color (or white in hot years). These are plants that we would have never purposely used in hand crosses to develop dark pink offspring, which may partly explain why Dr. Orton never recovered a dark-pink type earlier on when the germplasm to do so clearly existed in his collection. We are now studying the inheritance of this new dark pink color to better explain what we are seeing.

Figure 2. Range of colors and shapes of new seedlings expressing pink floral bract at Rutgers University in 2010. Insert on bottom right shows extreme range from very light pink blush to deep pink. Insert on bottom left shows size range and color variation.

Sometimes you just get lucky!

Over subsequent years of flowering, while we were impressed with the first 2 years' worth of seedlings and thought that we might have some potential dark-pink releases in those populations, it wasn't until some of the trees planted in 2009 flowered that we knew we had something special. One tree stood out immediately; it flowered heavy for the first time at only 4 years from seed (Figure 3). This was in contrast to most seedlings planted in the field that year that flowered at 5 years or later. In addition to flowering early, the tree had the darkest pink colored bracts (almost fuchsia) that we had ever seen (Figure 4). They glowed bright pink at a distance like no dogwood tree Dr. Orton nor we had seen before (Figure 5). I immediately thought it must be too good to be true; we kept quiet and waited for next year to see how it would perform.

Figure 3. Dogwood seedling field at Rutgers University in 2012. While most trees have few or no flower heads, one tree had many and its floral bracts were the darkest pink we had ever observed.

Figure 4. *Cornus kousa* 'Rutpink', Scarlet Fire® dogwood floral bracts at peak color.

Figure 5. The best attribute of 'Rutpink', Scarlet Fire® dogwood may be that it glows pink at a distance on a sunny day.

In 2013, the color was excellent again and with more flower heads on the 1-year-older tree, it was even more striking! We decided to propagate it that year to back it up and start to develop a stock block if needed. In 2014, the color was astounding again. At that time we started to consider releasing the plant and sent bud wood to a few nurseries to test its propagation attributes and build-up numbers. In 2015, the tree had great color again and by now the first propagated plants also bloomed dark pink. This is when we decided, despite the tree's relatively young age, to file for a patent (US PP28311 P3) and also share information with the nursery industry on its existence.

After several years of quiet deliberation, we decided to name the tree *C. kousa* 'Rutpink' Scarlet Fire® dogwood, in honor of the Rutgers University mascot the Scarlet Knight® and to also reflect the bright, fire-like glow of the plant in the landscape on a sunny

day. To date, plants have been distributed to more than 20 test locations around the country. They are being propagated by five licensed nurseries. Wholesale and limited retail sale started in 2016, with many more expected in 2017. So far, the trees are doing very well in liner production in Tennessee and Oregon. They are vigorous, free from disease, and form well-branched propagules. Only time will tell how successful the plant will be, as it is still in the very early stages of wider testing, utilization, and sale. We are excited about its potential as well as using it and its siblings in breeding.

We continue to use the wide germplasm base developed by Dr. Orton to focus on developing highly novel dogwoods that are attractive, healthy, and well-adapted and can be clearly differentiated from Scarlet Fire® dogwood and other exiting dogwoods in the market place. This would include developing plants with very large bracts, different bract shapes and colors, and interesting growth habits (upright, weeping, and mounding). We are also working with pure *C. florida* where we have identified a new source of powdery mildew resistance, and are currently moving the resistance genes into plants with excellent bract displays and a range of white to pink and red colors.

HAZELNUTS

Hazelnut production and resistance to eastern filbert blight

Before I was hired to run the ornamental breeding project in 2008, I had been working since 1996 on a nut tree research and breeding project at Rutgers. This was started by my mentor and world-renowned turfgrass breeder, Dr. C. Reed Funk. After a few years of examining the potential of many different temperate nut trees species, we decided to focus almost solely on hazelnuts (*Corylus* spp.). World production of hazelnuts is based on the European species *Corylus avellana*. Around 70% of world production comes from the Black Sea region in Turkey—and 15 and 5%, respectively, from Italy and the USA—primarily in the Oregon Willamette Valley. Other places of production include Spain, Chile, Azerbaijan, the Republic of Georgia, France, and China.

While production has been attempted in the eastern USA since colonial times, the disease eastern filbert blight (EFB) has made it largely impossible (Molnar et al., 2005). Eastern filbert blight is caused by the fungus *Anisogramma anomala*, which is endemic to a wide area east of the Rocky Mountains where it is associated with our native hazelnut *C. americana*. While EFB causes severe stem cankers and subsequent plant death of the European species, our native hazelnut is resistant or very tolerant. Small cankers can be found infrequently and rarely cause stem death. Unfortunately, however, our native hazelnut has very tiny, thick-shelled nuts and other attributes making it unsuitable for commercial production.

Fortunately, over the past two decades a lot of progress has been made identifying *C. avellana* plants that are resistant to EFB. At Rutgers, in close collaboration with Oregon State University, we made a number of seed-based germplasm collections of *C. avellana* across its native range in Europe and the Caucuses, grew many thousands of trees, and exposed them to the fungus. While most trees died, about 2% of the plants were found to be resistant and early tests are showing this resistance to be highly heritable. When combining these new plants with the work already ongoing in Oregon, we collectively have access to resistant parent plants from Spain, Turkey, Italy, Russia, Crimea, Georgia, Estonia, Latvia, Moldova, Chile, Poland, and Serbia (Capik et al., 2013; Colburn et al., 2015; Muehlbauer et al., 2014; Leadbetter et al., 2016). With our native *C. americana*, which hybridizes readily with the European hazelnut and produces fully fertile offspring, we have a very substantial pool of genetic resources to use in breeding for nut producing cultivars, pollenizers, and for ornamental landscape plants. Based on our substantial progress so far and huge market demand for the nut—the future of hazelnut production in the eastern USA looks very bright.

Ornamental hazelnuts

With many EFB-resistance genes available and the ability to hybridize between different species in the genus, it is now possible to focus efforts onto a wide array of

ornamental types. Within *Corylus* there exists purple leaf types, yellow leaf types, contorted stems, highly dissected "cut leaf" types (*C. avellana*), bright red and pink fall colors, small multi-stemmed shrubs (*C. americana*) to stately single trunk trees (*C. colurna* and *C. chinensis*), and peeling bark (*C. fargesii*) (Capik and Molnar, 2010). Our most exciting progress to date has been on backcrossing the purple leaf gene from *C. avellana* 'Rote Zeller' into our native *C. americana*, which is very cold hardy, EFB-resistant, has a compact, attractive growth form, and good fall color. Early on, we identified a chance hybrid seedling (*C. americana* × *C. avellana*) with purple leaves (likely an OP hybrid seedling crossed with *C. avellana* 'Rote Zeller', a widely grown sources of purple leaf color). In 2004, we crossed it with a "hybrid" seedling purchased from a nursery in Minnesota that looked very much like pure *C. americana*. We grew out the offspring and were impressed by their growth habits and color displays, with some expressing a more persistent dark purple leaf color and even nice fall color in some years. Unfortunately, at 5 years old all of the trees from this generation started to develop EFB.

We then decided to widen the gene pool and cross one more generation back to pure *C. americana*. We assembled a collection of clonal *C. americana* from the USDA NPGS repository in Corvallis, Oregon, representing select, improved plants from many regions across the native range. In total, we chose 14 parent trees to use in crosses representing 10 different states of origin. We collected pollen from the best five purple hybrid trees from the first generation of crosses, bulked the pollen, and used it as a common pollen "parent" on the 14 different *C. americana* selections. From this we harvested about 2,000 seed, germinated the seed keeping only the purple leaf seedlings (50% had green leaves) and planted them in the field for evaluation in 2010 (about 600 trees).

We exposed them to EFB by tying diseased sticks into the canopy of the trees and through natural spread from nearby heavily infected plots. By 2015, half of the trees were removed due to EFB or poor purple color retention of the leaves into the summer. However, we had a surprise this year! They flowered and set nuts for the first time and we recovered some of the most colorful nut husks (involucres) on a diversity of plants (Figures 5-7). We never expected we could get such bright, showy colors.

Figure 6. Diversity of husk types and striking red color found in *Corylus americana* backcross hybrids at Rutgers, and, at center, the color of leaves in late June in New Jersey.

Figure 7. Branch of *Corylus* showing display of red-color husks later in summer that can contrast well against the green leaves.

Now the job becomes identifying the best plants out of this population of very novel trees. In 2016, we selected the top 10 based on color retention and husk display; these were further selected to the best 2-3 that merit further testing and release. Propagation and testing are currently underway with the hopes for a release in 2018 or 2019, depending on performance across a range of locations and ease of propagation. These trees also produce tasty, edible nuts! Thus, these true edible ornamental plants may add some diversity to the palate of species available in the landscape—while potentially adding to the palate of homeowners as well!

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