Perennial plant breeding at Chicago Botanic Garden©

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INTRODUCTION

The Chicagoland Grows®, Inc. plant introduction program was founded in 1986 by the Chicago Botanic Garden, The Morton Arboretum, and the nursery consortium Ornamental Growers' Association of Northern Illinois (OGA). From its inception, the program has been dedicated to the development and introduction of superior landscape plants to the Midwestern USA and comparable climates in the USA, Canada, and Europe. Initially the program focused on the introduction of woody landscape plants, including numerous trees and shrubs from The Morton Arboretum's breeding research and historic landscape collections and selections from several regional nurseries. More recently, the program has also introduced several herbaceous perennials developed by regional nurseries and a garden center. In support of Chicagoland Grows, the Chicago Botanic Garden initiated a perennial plant breeding program in 1995, with its first introduction in 2004. Plant propagation for the Chicago Botanic Garden's breeding program was previously reported (Ault and Thomas, 2013). This report will focus on the breeding efforts of the program.

The breeding program's parameters are as follows. We have, for the most part, utilized taxa indigenous to North America, drawing on cultivated forms as well as wild-collected germplasm for breeding stock. Parent plants are selected based on their respective traits, crossed under controlled conditions, and their progeny assessed for continued breeding or potential introduction. Breeding has continued for as many as six generations beyond the original breeding stock. Most of the breeding projects have focused on developing interspecific hybrids, as advanced generation hybrids often exhibit novel flower colors and fragrances, plant habits, leaf and flower shapes, bloom times, etc., as well as broader environmental adaptability to temperature extremes, drought, soil pH, etc., than the original parents. When individual plants with introduction potential are selected out of the seedling blocks, they are clonally propagated (cuttings, division, tissue culture), and then trial blocks are evaluated for a minimum of 2 years at Chicago Botanic Garden. The best-performing plants are then propagated again and distributed for evaluation and production by a network of licensed nurseries. The timeline from the first interspecific cross attempted for a given genus to a plant selection becoming available at a retail garden center has been at least 7 to 10 years, longer for slower to mature taxa or for advanced generation selections to be developed and introduced.

SELECTED GENERA IN THE BREEDING PROGRAM

Baptisia, false indigo, breeding

The program has introduced four hybrid false indigos with eight more selections in nursery production, which are all being marketed under the Prairieblues™ false Indigo series. These are all interspecific hybrids with one exception. The program utilized the following species as its initial breeding stock: *Baptisia alba* (syns. *B. alba* var. *pendula, Baptisia alba* var. *alba*), *B. alba* var. *macrophylla* (syn. *B. leucantha*), *B. australis, B. australis* var. *minor, B. bracteata* (syn. *B. leucophaea*), *B. sphaerocarpa*, and *B. tinctoria*. In short, basically every interspecific hybrid combination attempted between the above species produced seed, and nearly all hybrid combinations developed proved to also be fertile. The most complex hybrid we developed combined four species and was still fertile. Therefore, the potential for combining these and other *Baptisia* species into a myriad of complex interspecific hybrids seems almost unlimited. Our selections and their parentage are found in Table 1.

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Table 1. Our selections and their parentage.

Introduction	Combination
Baptisia ×*variicolor* 'Twilite' PP#19,011 (2006 introduction)	*Baptisia australis* × *B. sphaerocarpa*
Baptisia ×*bicolor* 'Starlite' PP#19,971 (2007 introduction)	*Baptisia australis* × *B. bracteata*
Baptisia 'Midnight' PP#20,432 (2008 introduction)	(*Baptisia tinctoria* × *B. alba*) × *B. australis.*
Baptisia 'Solar Flare' PP#20,408 (2008 introduction)	[(*Baptisia tinctoria* × *B. alba*) × *B. australis*] × *B. sphaerocarpa*(?) or open-pollinated
Baptisia australis 'Blue Mound' PP#25,902	*Baptisia australis* (syn. *B. australis* var. *australis*) × *B. australis* var. *minor*
Baptisia 'Lavender Rose' PP#25,876	Advanced generation hybrid from *B. australis* and *B. bracteata*
Baptisia 'Lunar Eclipse' PP#25,875	Complex hybrid derived from *B. alba, B. australis, B. bracteata*, and *B. tinctoria*
Baptisia 'Mojito' PP#25,987	Complex hybrid developed from *B. australis, B. bracteata*, and *B. sphaerocarpa*
Baptisia 'Royal Purple' PP#25,508	Complex hybrid developed from *B. australis, B. bracteata*, and *B. sphaerocarpa*
Baptisia 'Sandstorm' PP#25,926	Advanced generation hybrid from *B. australis* and *B. bracteata*
Baptisia 'Spilled Buttermilk' PP#26,319	*Baptisia australis* × *bracteata* selection backcrossed to *B. bracteata*
Baptisia 'Sunny Morning' PP#25,479	*Baptisia sphaerocarpa* × *B. alba*

Here are some of the traits we observed for the species we utilized and their influence on our hybrids:

- *Baptisia alba*: plants were chlorotic and not terribly vigorous on our alkaline (pH = 7.6) clay soil. Our hybrid from it, *B.* 'Sunny Morning', also exhibits a preference for a neutral to acidic soil. But this species does impart purple tinted stems in the spring in its hybrids.
- *Baptisia alba* var. *macrophylla*: the northern genotype of this species tends to produce fewer stems than most of the other species, has no foliage on the lower stems, is one of the last to bloom, and also produces the longest inflorescences, all of which can be seen in its hybrids. These hybrids can take longer to mature in the garden, but the lack of lower foliage on strongly upright stems also results in the ability to interplant closer to other plants.
- *Baptisia australis* var. *australis*: the large vigorous form of the species is also the best known false indigo species. It imparts heat and cold tolerance, vigor, broad soil type and pH adaptability to its progeny, but habits can be irregular and hybrid progeny may grow huge; the original plant of *Baptisia* ×*variicolor* 'Twilite' grew as large as 5.5 ft tall and 9.5 ft wide, with no stem lodging!
- *Baptisia australis* var. *minor*: this is the southern genotype of the species. Germplasm from Texas proved vegetatively hardy in northern Illinois (USDA Zone 5), but flowering was limited. It imparts large flowers, a beautiful low dichotomously branching habit, and finer foliage, along with great heat adaptability and high soil pH tolerance. The true form should be utilized more in breeding, especially for USDA Zones 6 to 9.
- *Baptisia bracteata*: the southern genotypes did not prove to be hardy in northern Illinois. Even the regional genotypes proved to be temperamental in the garden. It is the earliest blooming species we used, the only one with horizontal inflorescences, and along with *B. australis* var. *minor* produces the largest flowers. Both the species and its hybrids are a bit more difficult to root from cuttings. It imparts early bloom, a compact habit, and heavy bloom with large flowers to its progeny. The horizontal inflorescences of the species don't seem to be passed along to its hybrids unless backcrossed to the species.

- *Baptisia sphaerocarpa*: another southern species (we trialed germplasm from Arkansas and Texas) that is perfectly vegetatively hardy and in most years floral bud hardy in northern Illinois. It imparts vigor, soil adaptability, and bushy habits to its progeny. Its yellow flower color is dominant when crossed to white-flowered *Baptisia* and blends when crossed with the blue-violet flowers of *B. australis* producing a mélange of violet, purple, copper, brown, and other odd-colored progeny.
- *Baptisia tinctoria*: the most vexing and intriguing species we utilized. It is the only repeat blooming species of the ones we used, producing short stems of yellow flowers from spring and then well into August. The airy stems and delicate small leaves give it a refined habit. However, southern genotypes did not prove hardy for us. Regional genotypes had to be grown on sharply drained soil, as it is native to almost pure sandy soils in Illinois and Indiana. The small flowers and short inflorescences proved fairly dominant in the crosses we made from it. Intriguingly, it did impart a slightly longer bloom period to our one released hybrid from it, *Baptisia* 'Midnight'. I would encourage breeders located where the species is more amenable to cultivation to work with it to capture its repeat bloom, but to avoid some of its less desirable traits.

***Echinacea*, coneflower, breeding**

The program has introduced four hybrid coneflowers, all marketed under the Meadowbrite™ coneflower series. These are all interspecific hybrids.

Echinacea 'Art's Pride' PP#15090 (Orange Meadowbrite™ coneflower) a 2004 introduction. The first orange-rayed coneflower in the marketplace was a second generation cross of *Echinacea purpurea* and *E. paradoxa*. We crossed the two species in 1998. The first generation hybrids between the two species bloomed in 2000 with light magenta ray flowers, and unlike either parent, were sweetly fragrant. These hybrid plants were crossed in 2000. The second generation hybrids bloomed in 2002 in an amazing melange of white, magenta, yellow, and orange ray flowers (Figure 1). It was from these plants that our introduction was selected in 2002. The hybrids were again all fragrant. Key to the development of orange hybrid coneflowers was the use of a white-flowered selection of *E. purpurea* in the original cross. The cross of *E. purpurea* using the typical magenta ray flowered forms × *E. paradoxa* produced second generation hybrids in muddy magenta, rusts, and violets.

Figure 1. *Echinacea purpurea* × *Echinacea paradoxa* hybrids at Chicago Botanic Garden.

Echinacea 'CBG Cone3' PP#16636 (Mango Meadowbrite™ coneflower) a 2004 introduction. The rays are mango yellow in color. This selection arose as a mutation in tissue culture from *Echinacea* 'Art's Pride' (above), which highlighted the challenge of producing large numbers of coneflowers in tissue culture in earlier years. It proved to be stable when intentionally propagated in tissue culture. I have not encountered any recent reports of *Echinacea* being unstable in tissue culture, presumably a result of the tissue culture protocols being refined over time.

The two selections above and other early orange and yellow-rayed hybrid coneflowers developed from the same parent species by fellow breeders proved to be culturally challenging, often being short-lived in garden cultivation. This challenge no doubt arose from the *E. paradoxa* ancestor. This species is found in limestone glades in the Ozarks, where it is adapted to high pH, limited nutrient availability, and exceptional soil drainage. It forms a taproot adapted to coursing deep into a rock crevasse — not our typical garden cultivation conditions! *Echinacea purpurea* × *E. paradoxa* hybrids appear to be perfectly fertile though, and so advanced generation crosses being made by other breeders are proving more amenable to cultivation, either through careful selection and/or by backcrossing to other, easier to cultivate and maintain garden forms of *E. purpurea*.

Echinacea 'CBG Cone 2' PP#18546 (Pixie Meadowbrite™ coneflower). A more complex interspecific hybrid that combined two hybrid lines. We crossed *E. purpurea* 'Magnus' × *E. tennesseensis* in 1996 and then *E. angustifolia* × *E. tennesseensis* in 1997. Both hybrid lines proved to be reasonably fertile. The former cross was quite vigorous and garden-adaptable, but most of the progeny disconcertingly produced tall inflorescences (like the *E. purpurea* parent) that then branched high up the stems producing multiple flower heads per stem (like the *E. tennesseensis* parent). The stems on most of these hybrids tended to lodge, but a few more compact forms were eventually selected. The *E. angustifolia* × *E. tennesseensis* hybrids were compact, bushy, and floriferous, but a challenge to grow culturally on our wet clay soils (both parent species originate from well drained soils in drier habitats). The two hybrid lines were crossed in 2000 (*E. purpurea* 'Magnus' × *E. tennesseensis,* the seed parent), and the selection made in 2002. It wasn't introduced until 2007, as it proved more difficult to root in tissue culture. But once introduced, it became popular for its bushy, compact habit, and its ability to bloom from July to September (in USDA Zone 5), producing a plethora of flower heads with perky, upturned magenta rays. It appears to have a higher aster yellows resistance than other selections. Time has also proven it to be one of the longer-lived coneflowers currently in cultivation (we have observed high survival of 5-year-old plants). Gardens could use more *E. tennesseensis*-influenced hybrids. However, there are challenges in breeding with this species. *Echinacea tennesseensis* × *E. paradoxa* hybrids were all mules (sterile). Our *E. tennesseensis* × *E. purpurea* hybrids were very difficult to cross to our *E. purpurea* × *E. paradoxa* hybrids, and when we were successful in combining these hybrid lines, the progeny invariably had inferior plant habits and produced ray flowers in muddy colors that faded with age. Our most promising lines that we unfortunately abandoned for other projects were advanced generation crosses of white-flowered *E. purpurea* × *E. tennesseensis*. We produced a few hybrids similar to the Pixie Meadowbrite™ coneflower only with white rays and green disks. These also proved difficult to propagate in tissue culture and so were never introduced. I highly encourage other breeders to purse this line of breeding for longer lived and garden adaptable coneflowers.

Echinacea 'Burgundy Fireworks' PP#23,691. Selected in 2006 and introduced in 2012 for its compact habit, upturned dark burgundy rays that are fused into tubes, and its dark violet tinged foliage and stems, this selection has a complicated pedigree. The fused ray trait appeared as a mutation in a line of *Echinacea* [*laevigata* × *purpurea*] × [*tennesseensis* × *laevigata*]. The dark stems and foliage was derived from a line of *Echinacea* [*purpurea* × *tennesseensis*] × *purpurea*. These two lines were crossed and the progeny then sibbed to segregate 'Burgundy Fireworks'. Most of the selection's sibs were very inferior in habit, but were still quite fertile, indicating there are various lines of interspecific coneflowers that could be pursued. The fused ray trait appeared several times in a number of coneflower lines. During the breeding of 'Burgundy Fireworks' its fused ray trait was shown to be a

simple recessive trait, and could therefore be in theory programmed into other lines in two generations of crossing.

For a more detailed though earlier accounting of *Echinacea* breeding, see Ault (2006).

***Phlox,* phlox, breeding**

Despite the ongoing popularity of phlox, notably the spring-blooming moss phlox, *Phlox subulata* and its relatives, and the summer blooming garden phlox, *Phlox paniculata*, relatively few of the 65 or so species of phlox are represented in the trade, and fewer still interspecific hybrid phlox are available. Probably the most commonly grown interspecific phlox currently in cultivation are *P.* ×*arendsii* (*P. paniculata* × *P. divaricata*) hybrids, *P.* ×*procumbens* (*P. subulata* × *P. stolonifera*) hybrids, and hybrids of *P. subulata* and *P. bifida* that are masquerading as *P. subulata* selections. There are also a handful of hybrid phlox out of Europe (many more selections are sold there), sold as *P.* ×*douglasii* hybrids (an invalid designation as there is a species *P. douglasii*, and so the hybrid name of the same is incorrect). These are reputedly hybrids of *P. subulata* with various western phlox species, or hybrids between various western species. Their actual parentages are not known.

There are challenges to developing interspecific phlox hybrids. Many of the species won't hybridize readily with one another, and some of the combinations that have been successful can only be made in one direction (Zale and Jourdan, 2012). I suspect many of the interspecific hybrids are infertile or only with very low fertility, making advanced generation breeding and selections difficult, if not impossible. *Phlox* ×*procumbens* seems to fall into the infertile category, for example. Some interspecific hybrids are fertile, such as *P. subulata* × *P. bifida*, which allows for more interesting trait selection in advanced generations. Also restricting the development of more interspecific hybrid phlox is the lack of availability of most of the species in the horticultural trade, which can be confounded by the exacting cultural requirements of most of the western desert or montane species.

With these caveats in mind, we launched an interspecific phlox breeding program at Chicago Botanic Garden in 2002. Given the relative ease of cultivating the eastern phlox species, most of our early efforts were directed towards crossing various eastern species. We had many more failures than successes. Most of the crosses attempted between *P. carolina, P. divaricata*, *glaberrima* subsp. *triflora* (=*P. triflora*), *P. ovata* (=*P. latifolia*), *P. maculata, P. paniculata, P. pilosa*, *P. stolonifera*, *P. subulata*, and others failed to produce seed, or the limited seed produced often failed to germinate. One odd hybrid was produced from *P. paniculata* × *P. stolonifera* that produced a stout stem or two upright in spring and then lodging in summer, with a small terminal cluster of pinched flowers. It died after a few years in the garden. Due to the limited germplasm we had for some of these species, the reciprocal crosses were not always attempted, which may have enhanced seed set for some of the crosses. One outstanding plant did come from this earlier work, that being *P.* 'Forever Pink' PP# 24,918, a 2013 introduction from a cross made in 2007. Originally thought to be a cross of *P. buckleyi* × *P. carolina*, careful examination of the two parent plants in later years proved them to both be *P. glaberrima* subsp. *triflora* selections; this highlights the difficulty in proper identification of some of the more arcane phlox selections in cultivation.

In more recent years, we have concentrated our efforts on spring-blooming, interspecific hybrid phlox. We have been evaluating and attempting to cross eastern taxa (*P. subulata, P. nivalis, P. stolonifera*), midwestern (*P. bifida*), and western taxa (*P. albomarginata*, *P. alyssifolia, P. condensata, P. grayi, P. kelseyi, P. diffusa*). As reported in the literature, *P. bifida, P. nivalis* and *P. subulata* are all proving to be interfertile, and in fact many of the supposed *P. subulata* cultivars in cultivation are likely a muddle of hybrids of these three species. All three species and their hybrids prefer well drained soils, full sun, and reasonable moisture availability. *Phlox bifida* naturally occurs either on sandy soils or on limestone outcrops in the Midwest. I have not rigorously evaluated selections of both ecotypes to test if their breeding behaviors vary. Crosses of *P. bifida* with *P. subulata* and *P. stolonifera* have produced vigorous, mounding plants with cleft-petals (hence the bifida species epithet for *P. bifida*). These are proving garden amenable and quite hardy. The *P. bifida* × *P. subulata* hybrids we have developed have been fertile, but the few *P. bifida* × *P. stolonifera* hybrids we have

developed have been sterile.

Phlox ×*procumbens* (*P. subulata* × *P. stolonifera*) is proving to be an odd case. There are a few cultivars in the trade, and we introduced in 2015 our own selection, *P.* ×*procumbens* 'Pink Profusion' PP# 25,883, which produces large one-plus inch wide flowers in deep purple pink. It has been performing better further south (Zones 6-8) than up north (Zones 4-5), not surprising given both of the parents are from the mid-Atlantic region and further south. 'Pink Profusion' appears to prefer a well-drained soil, full sun, and good moisture availability. Given one parent is found on rocky ledges and slopes in good sun (*P. subulata*) and the other is a moist, woodland or shaded streamside plant (*P. stolonifera*) predicting its preferred habitat is a challenge. Crosses like this between species from very divergent habitats need broad testing to determine how they are best cultivated. If all of the *P.* ×*procumbens* cultivars are sterile (the ones we have tested appear so) this limits being able to line breed them and select for different garden conditions.

The aforementioned western species have proven to be a real challenge to keep alive, let alone grow well, in northern Illinois. Our best successes have been in a deep sand bed filled with coarse quartz-sand plus some organic matter. The western taxa hold promise for a variety of factors, including high pH tolerance (*P. albomarginata*, *P. alyssifolia*), high salinity tolerance (*P. kelseyi*), fragrance (*P. multiflora*), shade (*P. diffusa*), drought, heat, cold and other tolerances, as well as novel flower colors, foliage traits, etc. Most of these western taxa are barely represented in cultivation, and there are selected forms reasonably available only of *P. kelseyi* ('Lemhi Midnight' and 'Lemhi Purple'). Two of our first successful interspecific hybrids were *P. albomarginata* × *P. kelseyi* and *P. alyssifolia* × *P. kelseyi*, both producing very compact plants with light violet flowers. The former has produced a few seed in further crossing; the latter appears to be sterile. Our best success to date is a 2015 introduction, *Phlox* 'Violet Pinwheels' PP# 25,884, which resulted from a cross made in 2008 between *Phlox bifida* and *Phlox kelseyi* 'Lemhi Purple'. Its spring flowers with uniquely upturned petals are a deep violet purple, different from most other spring blooming moss phlox in the trade. 'Violet Pinwheels' requires a well-drained soil, good light, and a uniform moisture supply during its growing season. Our effort to cross these and hopefully other phlox species is ongoing.

Veronica, speedwell, breeding

The program has introduced two speedwells. *Veronica* 'Whitewater' PP#22783, introduced in 2011, is a white-flowered branch sport of the popular 'Waterperry Blue', discovered by John Wachter of Elite Growers, Inc. It is an excellent groundcover for sun to partial shade with adequate moisture supply. It carpets itself with glistening white flowers in spring, and can repeat bloom later in the season. Like its clonal parent, it also produces attractive red fall foliage. *Veronica* 'Tidal Pool' PP#23,341, selected in 2009 from a cross made at Chicago Botanic Garden in 2007 between *Veronica armena* and *V. pectinata* 'Rosea' and then introduced in 2012, is a very adaptable groundcover for drier sites and full sun, producing its dark blue-violet flowers in spring followed by attractive and disease resistant foliage all summer. A number of interspecific hybrids were developed at the Chicago Botanic Garden, mostly between the drier habitat, groundcover types, but most of them proved to be poorly adapted to our seasonally wet, poorly drained clay soils and high summer humidity. For the sake of disclosure to assist other breeders, here is a list of the crosses that definitely produced hybrids. Note: *Veronica* taxonomy is a muddle, and some of the selections in cultivation may not be correctly identified to species. Caveat emptor! The most promising crosses we made are marked with an *: **V. alpina* 'Alba' × *V. spicata* 'Silbersee', *V. allionii* × *V. spicata* subsp. *incana*, *V. stelleri* 'Mann's Variety' × *V. allionii*, *V.* 'Giles van Hees' × *V. spicata* subsp. *incana*, *V. armena* × *V.* 'Blue Reflection', **V. turrilliana* × *V. cuneifolia* ssp. *Issaurica*, **V. cuneifolia* × *V. turrilliana*, **V. liwanensis* × *V. oltensis*, *V. oltensis* × *V. armena, *V. cuneifolia* × *V. armena.* A few more-moisture tolerant groundcover speedwell hybrids are still being evaluated at Chicago Botanic Garden.

Other, currently active breeding projects at Chicago Botanic Garden will be presented at a future date.

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