Combined Proceedings IPPS 68:99-107. 2018.

Cold Hardiness: Successes and Failures at the University of Delaware Botanic Garden

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Keywords: plant collections, germplasm, evaluation, winter hardiness, witchhazel, palms, *Camellia*, *Magnolia*, *Itea*, *Osmanthus*, *Quercus*, *Viburnum*, *Agave*.

INTRODUCTION

Botanic gardens and arboreta have always played an important role in the maintenance and testing of novel germplasm. By their very nature, the diverse collections of plant material provide germplasm to the trade, an opportunity to assess cultural requirements and information regarding the adaptability of diverse plants to varying environments. Structured programs such as the Plant Collections Network sponsored by American Public Gardens Association and the USDA-Agricultural Research Service seek to coordinate a network of gardens to build a national collection of plants and facilitate access to these plants and information generated by the program. Whether collections in public gardens are part of a larger regional, national or international effort their value is increasing rapidly as the nursery industry evolves to maintain economic viability. Nurseries that maintain diverse inventories have significantly reduced their diversity to increase efficiency and maximize profits. Many nurseries that historically produced amazingly diverse plant lists have either greatly reduced the selection or even gone out of business. The result of this economic reality results in an ever-increasing role for public gardens to maintain diverse collections and provide basic information on the adaptability of the collections.

MATERIALS AND METHODS

The University of Delaware Botanic Gardens (UDBG) is located in Newark, Delaware at the transition of the coastal plain and piedmont region of the Eastern United States in USDA Zone 7a. The soil is a silt-loam that may have minor drainage issues, particularly in areas lacking topography. All information regarding plant survivability is based on plants planted in the ground, not containerized specimens. Several microclimates exist within the UDBG. There are "courtyard" areas adjacent to Townsend Hall that are surrounded on three sides by the

building, only open to the east. Most potentially marginally hardy plant material is first evaluated in these areas. If the material proves to be reasonably cold hardy in these areas, plants are established in more exposed areas of the UDBG for final evaluation.

This paper focuses on broadleaf evergreen plants that may be questionably hardy in Zone 7a. It is not a complete list of accession in the UDBG collection in a particular genus, rather those that are marginally hardy based on the literature. Most all succulents are planted in raised beds with the courtyards. The soils in these beds was removed to a depth of 1m. The soil was mixed with approximately 75% sharp sand and the beds were filled with the sand-soil mix.

Weather data was collected by an automated weather station, part of the Delaware Environmental Observing System; the station name is Newark, DE-Ag Farm, immediately adjacent to the UDBG. The weather data is available at: http://www.deos.udel.edu/.

Plants are evaluated for survivability as either alive or dead, dead plants are deaccessioned from the plant records. Occasionally, more detailed notes are made regarding winter damage. There are no attempts to provide additional winter protection, even in the first year of establishment.

While winter hardiness is a combination of many factors, not limited to drainage, physiological conditions leading into the winter, and rate of temperature change, the USDA hardiness map uses the average annual extreme minimum temperature as a relative measure of winter hardiness. As a point of reference, the annual extreme minimum temperature will be used in this work.

RESULTS

As to be expected, there is great variation of the lowest annual temperature. During the period of this study, the lowest reported temperature was -5°F and the warmest winter recorded 19°F as the lowest annual temperature (Figure 1). Temperatures approximated 0°F in the winters of 1996, 2005, 2014 2015, and 2018 during the period of this report. These years, along with 1994 were the greatest challenge to plants in the collection. The average annual extreme minimum temperature for this period was 7.4°F.

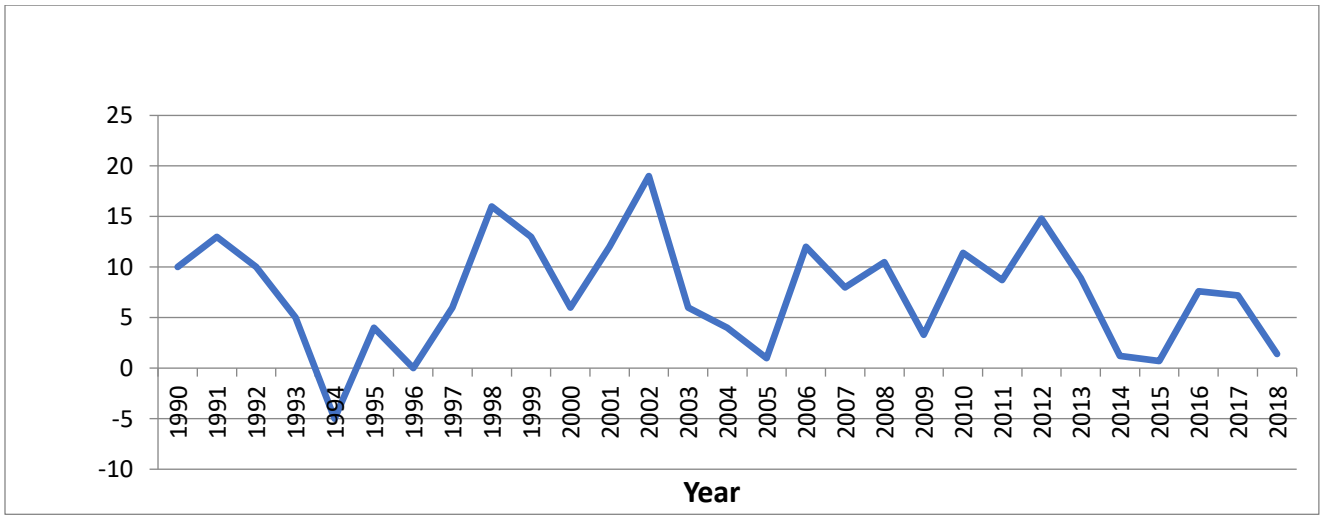

Figure 1. Lowest annual temperature at UDBG by year.

One major genus in the UDBG's collection is *Camellia*. The major emphasis of this collection is at the species level, not the cultivar level. Results of survivability of these plants are presented in Table 1. The Ackerman hybrids have been consistently hardy. Flowers begin in October-November and continue until a killing frost. Unopened flower buds never open the following spring, rather are frozen by the cold during winter. The *C. japonica* specimen was a seedling that originated from a Morris Arboretum collection trip to Korea. The plant survived 1994 (-5°F) unscathed with all flower buds opening in the spring. It has never had any winter foliar or flower bud damage. *Camellia sasanqua*, represented by the species and a single cultivar, has proven reliably hardy. Undoubtedly, some of the many cultivars would suffer winter damage or die if grown in the collection. The various species that have survived typically survive the winters with little to no damage. *Camellia rosaeflora* has died in three separate plantings, established in different years.

Table 1. Survivability of Various Species of *Camellia* in the UDBG.

Species	Year accessioned	Year deaccessioned
C. 'Winter's Charm'	1994	Alive
C. 'Winter's Interlude'	2007	Alive
C. 'Winter's Joy'	2007	Alive
C. 'Winter's Waterlily'	2007	Alive
C. chekiangoleosa	2011	2015[1]
C. chrysanthoidies	2011	2012
C. crapnelliana	1999	2000
C. cuspidata	2011	Alive
C. edithae	1999	2000
C. euryoides	2015	2016
C. fraterna	1999	2000
C. furfuracea	2011	2012
C. × *hiemalis*	2011	Alive
C. japonica	1991	Alive
C. japonica 'Spring Promise'	2009	Alive
C. longicarpa	1999	2000
C. lutchuensis	2011	2014[1]
C. octopetala	2011	Alive
C. oleifera	1995	Alive
C. rosaeflora	2011	2014[1]
C. sasanqua	1995	Alive
C. sasanqua 'Long Island Pink'	2005	Alive
C. saluenensis	1999	2000
C. sinensis	2006	Alive
C. transnokoensis	2011	2013
C. truncata	2012	Alive
C. yuhsienensis	2012	Alive

[1]Lowest temperature near 0°F for this year.

Another priority collection are plants in the witchhazel family (Hamamelidaceae). The winter performance of these plants is presented in Table 2. In general, the *Distyllium* species and cultivars have performed well. Several of the cultivars have been established outside of the protected courtyards. Even in these more open situations plants survive the winter with no to minor winter burn and/or dieback in severe winters. *Loropetalum chinense* 'Roseum' was received as a cutting, grown on, and planted in 1994 and survived -5°F its first year with significant dieback. It typically will partially defoliate in most winters and suffered dieback in severe winters but the original plant has survived 24 years. *Parrotiopsis* (deciduous), *Sinowilsonia* (deciduous), *Sycopsis* (evergreen), and *Sycoparrotia* (primarily deciduous) have all thrived in the collect with no winter damage.

Table 2. Survivability of various species of *Hamamelidaceae* in the UDBG.

Species	Year accessioned	Year deaccessioned
Distylium 'Athen's Tower'	2018	Alive
D. 'PIIDIST-II' Blue Cascade™	2014	Alive
D. 'PIIDIST_V' Cinnamon Girl™	2015	Alive
D. 'sPg-3-007' Spring Frost™	2015	Alive
D. 'Vintage Jade'	2014	Alive
D. buxifolium	2018	Alive
D. myricoides	1999	Alive
D. racemosum	1999	Alive
Loropetalum chinense 'Roseum'	1994	Alive
L. chinense 'Chang Nian Hong' Ever Red® fringe flower	2015	2018
L. chinense 'Shangi-hi' Purple Diamond® fringe flower	2015	Alive
Parrotiopsis jacquemontiana	1997	Alive
Sinowilsonia henryi	2013	Alive
Sycopsis sinensis	1989	Alive
×*Sycoparrotia semidecidua*	1989	Alive

The evergreen species of *Itea* were obtained from several nurseries. The winter performance is listed in Table 3. Both *I. oldhamii* and *I. yunnanensis* were received as *I. chinensis*. *I. oldhamii* is less hardy than the other species, dying in the winter of 2015 after surviving two other winters of near 0°F. *I. ilicifolia*, has twice died the first winter after planting.

Table 3. Survivability of various species of *Itea* in the UDBG.

Species	Year accessioned	Year deaccessioned
I. chinensis	1992	Alive
I. ilicifolia	2015	2016
I. oldhamii	1999	2016
I. yunnanensis	1997	Alive

The survivability of several *Osmanthus* species and cultivars is listed in Table 4. Only *O. fragrans* and *O. fragrans* var. *aurantiacus* have suffered partial defoliation to significant dieback after severe winters with once specimen dying after 0°F even though plants are grown with winter protection in the courtyard. Most other specimens are grown in more exposed landscape situation. *O. ×fortunei*, planted in an open field, suffered complete defoliation and significant dieback after -5°F.

Table 4. Survivability of various species of *Osmanthus* in the UDBG.

Species	Year accessioned	Year deaccessioned
O. americanus	1997	Alive
O. armatus	2012	Alive
O. decorus 'Beki Kasapligil'	1999	Alive
O. delavayi	2012	Alive
O. fragrans	1997	2018
O. fragrans var. *aurantiacus*	2012	Alive
O. × *fortunei*	1966	Alive
O. × *fortunei* 'San Jose'	1998	Alive
O. hererophyllus 'Goshiki'	1997	Alive
O. hererophyllus 'Gulftide'	1998	Alive
O. hererophyllus 'Kembu'	1997	Alive
O. hererophyllus 'Purpureus'	1998	Alive
O. hererophyllus 'Sasaba'	2012	Alive
O. megacarpus	2012	2013[1]

[1]Death of plant due to mechanical damage.

The survivability of various palm species is presented in Table 5. Several of the accessions have not yet experienced a winter. To date, *Rhapidophyllum* has thrived, never showing winter damage. *Sabal minor* has survived for 12 years but produces little new growth. *Sabal lousiana* has survived 5 years and has increased in size nicely.

Table 5. Survivability of various species of palms in the UDBG.

Species	Year accessioned	Year deaccessioned
Butia capitata	2015	2016
Rhapidophyllum hystrix	1998	Alive
Sabal minor	2006	Alive
Sabal minor 'Chipola Dwarf'	2018	Alive
Sabal minor 'McCurtian'	2018	Alive
Sabal lousiana	2013	Alive
Sabal uresana	2018	Alive
Sabal palmetto	2010	2011
Trachycarpos fortunei	2011	2012
Trachycarpus fortunei 'Wagnerianus'	2018	Alive

The data for the genus *Magnolia* represents, primarily, the evergreen species with a few select deciduous species/cultivars. This is only a portion of the *Magnolia* species/cultivars grown in the collection. Several of the evergreen species were formerly listed

as *Michelia* but are listed here as *Magnolia*. The survivability data is presented in Table 6. *M*. 'MicJUR01' and *M*. 'Free Spirit' (both formerly *Michelia*) did suffer some dieback during the near 0^{O}F winters of 20014, 2015 and 2018 but plants recovered well and flowered in subsequent years. *M. figo* has grown well and survives cold winters with minor foliar burn but flowers well in the spring. All *M. grandiflora* cultivars have grown well with minimal to no winter damage. Even *M. grandiflora* 'Little Gem' has not suffered winter damage since the early establishment years. *M. insignus* dieback every year until it ultimately died. *M. yuyuanensis* never shows winter damage, is fully evergreen and flowered for the first time in spring of 2018.

Table 6. Survivability of various species of *Magnolia* in the UDBG.

Species	Year accessioned	Year deaccessioned
M. 'Caerhays Belle'	1997	Alive
M. 'MicJUR01' Fairy Magnolia® Blush	2012	Alive
M. campbellii var. mollicomata	1994	1996[1]
M. figo	1992	Alive
M. x*foggii*	1996	1996[1]
M. grandiflora 'Brakens Brown Beauty'	1994	Alive
M. grandiflora 'D. D. Blanchard'	1993	Alive
M. grandiflora 'Glen St. Mary'	1994	Alive
M. grandiflora 'Little Gem'	1993	Alive
M. grandiflora 'MGTIG' Monrovia's Greenback™ magnolia	1998	Alive
M. grandiflora 'Samuel Sommer'	1993	Alive
M. grandiflora 'Victoria'	1993	Alive
M. grandiflora 'Copper Top'	2018	Alive
M. grandiflora 'Edith Bogue'	1989	Alive
M. grandiflora 'North Star'	1993	Alive
M. grandiflora 'Russett'	1994	Alive
M. grandiflora 'Southern Charm' Teddy Bear® magnolia	2015	Alive
M. insignus	2012	2015[1]
M. maudiae	2013	Alive
M. yunnanensis 'Free Spirit'	2013	Alive
M. yuyuanensis	2012	Alive

[1]Lowest temperature near 0^{o}F for this year.

Many of the *Mahonia* in the UDBG collection have grown well and survived for many years (Table 7). Most of these are grown with the protection of the courtyard which has mediocre drainage. Several of the species died within two to three years of planting during winters that were rather mild, suggesting the drainage may be responsible for the demise of the plants. *M.* ×*media* cultivars grow with mixed results. Those that have survived have grown well, producing flowers that begin in November and continue into December and January.

M. eurybracteata 'Soft Caress' died the 1st year after planting when temperature approached 0^{o}F. New specimens were planted in 2018, along with *M*. 'sPg-15-1' to determine the suitability of these popular, fine textured cultivars.

Table 7. Survivability of Various Species of *Mahonia* in the UDBG.

Species	Year accessioned	Year deaccessioned
M. 'Arthur Menzies'	2000	Alive
M. 'sPg-15-1' Beijing Beauty™	2018	Alive
M. aquifolium	1998	Alive
M. bealei	1978	Alive
M. duclouxiana	1999	Alive
M. eurybracteata 'Soft Caress'	2015	2016
M. fortunei	1999	Alive
M. gracilipes	1999	Alive
M. japonica	2012	Alive
M. × *lindsyae* 'Cantab'	2000	2003
M. lomariifolia	1999	Alive
M. mairei	1999	Alive
M. × *media* 'Charity'	2000	Alive
M. × *media* 'Hope'	2000	2003
M. × *media* 'Lionel Fortescue'	2005	Alive
M. × *media* 'Underway'	1999	2002
M. × *media* 'Winter Sun'	2000	Alive
M. napaulensis 'Maharajah'	1999	2001
M. nervosa	1999	2003
M. pinnata 'Ken Howard'	1999	2001
M. piperiana	1999	2001

The oaks which are represented in Table 8 are either evergreen or species of questionable hardiness, other species in the collection are not represented. Most of the deciduous species have grown well without any winter damage. *Quercus myrsinifolia*, obtained from Morris Arboretum, has grown well with only minor defoliation in particularly severe winters. *Quercus virginiana* was wild collected in the vicinity of Wilmington, NC and has grown well but has some defoliation to near complete defoliation in severe winters but has never demonstrated dieback.

Table 8. Survivability of Various Species of *Quercus* in the UDBG.

Species	Year accessioned	Year deaccessioned
Q. aliena	1993	Alive
Q. dentata	1993	Alive
Q. geminata	2016	2017
Q. incana	2007	2010
Q. laurifolia	1991	Alive
Q. lyrata	1991	Alive
Q. myrsinifolia	1994	Alive
Q. nigra	1991	Alive
Q. nutallii	1991	Alive
Q. laurifolia	2016	2017
Q. virginiana	2008	Alive

Survivability for several genera/species of "succulent" plants are presented in Table 9. All of these plants have been grown in an amended soil, approximately 75% sand by volume. To date, none of the *Agave* have survived more than two years. *Dasylirion acrotrichum* and *Nolina microcarpa* are the only species in their respective genera to survive multiple years to date. Most *Opuntia* species grown have survived. The *Yucca* species are more tender representative grown in the UDBG but have survived well. Many of these plants have yet to grow through a winter.

Table 9. Survivability of various species of succulents in the UDBG.

Species	Year accessioned	Year deaccessioned
Agave 'Blue Glow'	2018	Alive
Agave 'Mr. Ripple'	2016	2018
Agave americana	2008	2010
Agave havardiana	2018	Alive
Agave ×*loferox*	2018	Alive
Agave polyacantha	2016	2017
Agave univittata	2016	2018
Agave victoriae-reginae	2006	2008
Agave virginica	2016	2018
Dasylirion acrotrichum	2008	Alive
Dasylirion berlandieri	2018	Alive
Dasylirion leiophyllum	2018	Alive
Dasylirion longissimi 'Toothless Spoon'	2006	2008
Dasylirion texanum	2015	2018
Dasylirion wheeleri	2008	2010
Hesperaloe parviflora	2008	Alive
Nolina microcarpa	2006	Alive
Nolina nelsonii	2006	2008
Opuntia cacanapa 'Ellisiana'	2017	2018
Opunti fasilaris 'Baby Rita'	2016	Alive
Opuntia humifusa	2010	Alive
Opuntia polycantha	2016	Alive
Yucca constricta	2008	Alive
Yucca harrimmaniae	2015	Alive
Yucca treculeana	2016	Alive

The UDBG has a significant collection of viburnums. Only the broad-leaved evergreen and a few marginally hardy species are represented in Table 10. Most of these are growing in the protected courtyard while the rest of the collection is distributed throughout the garden. *Viburnum davidii* struggled for the years that it survived. It appeared as the summer heat and humidity stressed the plants as much as the cold of winter. There was not a significantly cold winter during the period the plant was in the garden, yet it died, further suggesting that summers were as stressful as winters. Several other species survived for only a few years and died following relatively mild winters suggest that the plants never established well. These are good potentials for reevaluation.

Table 10. Survivability of various species of *Viburnum* in the UDBG.

Species	Year accessioned	Year deaccessioned
V. atrocyaneum	1999	2000
V. awabuki 'Chindo'	1999	Alive
V. cinnamomifolium	2013	Alive
V. cylindricum	2005	Alive
V. davidii	1998	2002[1]
V. foetidum	2003	2004
V. harryanum	1999	2001
V. ×hillieri 'Winton'	2013	Alive
V. japonicum	1997	Alive
V. obovatum 'Mrs. Schiller's Delight'	2013	2015
V. obovatum 'Reifler's Dwarf'	2014	Alive
V. propinquum	1988	Alive
V. tinus	1995	Alive
V. utile	1997	Alive

CONCLUSIONS

Many factors other than the lowest temperature determine if a plant will survive the winter. The rapidity of transition from hot to cold and back, temperature fluctuations during the winter, soil moisture, stress going into the winter and more will impact winter performance. Reported here is only the lowest temperature as an attempt to gauge winter hardiness.

Plants that are well established, growing vigorously, also tolerate a challenging winter better than those recently planted. Many of the plants lost during these trials where lost in the first year. Some of these years were particularly cold, others were not. Replanting specimens that died after the first year would give a better measure of the reliability of these plants, particularly when plants are challenged the first winter after planting. In some cases, this has been done, in others it still needs to be repeated.

Many of these evaluations occur in a protected microclimate, as illustrated by the survival of pinapple guave, *Feijoa sellowiana* (USDA Zone 8-10) for eight years in the same conditions. Future efforts will focus on establishing additional plants into more typical, exposed conditions throughout the garden. Those plants that were evaluated outside of the microclimate of the courtyard have proven their adaptability to "typical" landscape conditions in Newark, DE.

The UDBG continues to plant new plants of questionable hardiness to test their survivability under field conditions in the mid-Atlantic region. A major goal of the garden is to develop a broadly diverse collection of plants that serve as an illustration of what is possible to grow, and the diversity of plants available beyond the typical nursery trade. It is a resource to the trade, the public and the university community.