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Suitability of Cultivated Forms of Native Shrubs to Support Pollinators

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Suitability of Cultivated Forms of Native Shrubs to Support Pollinators

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Approval Page

Masters of Science Thesis

Suitability of Cultivated Forms of Native Shrubs to Support Pollinators

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This thesis is dedicated to my father, Casey Ricker.

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Literature Review

As demand increases for more versatile and functional landscapes, native plants are becoming a popular choice for growers and gardeners (Halleck, 2015; Simakis, 2016). A native plant is one that has originated in or arrived in an area without human intervention of any kind (Pyšek et al., 2004). Natives are characteristically hardier, more drought tolerant, require less maintenance, and better support the environment than non-native plants. Native plants are being promoted as replacements for non-native invasive plants and are an emerging garden and landscape trend recognized by growers. In addition, many consumers want to help support native pollinators and honey bees through gardening with natives. The decline in pollinator populations is due in part to loss of available nectar and pollen supply in the landscape (Vaudo et al., 2015; Potts et al., 2016). Currently, most of the native plants available from nurseries are cultivars and not straight species. A cultivar is a selected genotype that exhibits superior ornamental characteristics and landscape performance to the species. The use of native plant cultivars, commonly called nativars (Armitage, 2008), has incited questions about their ability to support native pollinators and honeybees as well as the straight species (Becker, 2015; Botts, 2014). The objective of my research is to evaluate pollinator support of native shrub species and their cultivars through analysis of pollinator visitation, floral morphology, and nectar supply. The following will include a review of the current literature on cultivar support for pollinators and methods of measuring pollinator visitation, floral morphology, and nectar supply.

Pollinator Support of Ornamental Plants

To assess a plant's potential support for pollinators or other organisms, plants need to be judged by their ability to supply adequate forage. Plants are primarily evaluated for nectar,

pollen, and flower quantity and quality, and pollinators are counted or collected (Comba et al., 1999a; Harris et al., 2016; Garbuzov & Ratnieks, 2014). Pollinator support studies have been more frequent due to the increased interest in providing adequate forage and shelter in wildlife conservation. To date most pollinator studies have compared the abilities of exotic ornamental plants (Comba et al., 1999a; Yeargan & Colvin, 2009; Harris et al., 2016), and ornamental exotics and natives, (Comba et al., 1999b; Garbuzov & Ratnieks, 2014) with few studies reaching native plants and their cultivars (Troy, 2013; Poythress & Affolter, 2014; White 2016).

A study of butterfly visitation and diversity for four *Zinnia* cultivars (Yeargan & Colvin, 2009) found that one cultivar, *Zinnia violacea* ‘Lilliput’ attracted more than twice the number of butterflies and had the greatest diversity of butterfly species than the other 3 cultivars. Harris et al. (2016) documented the beneficial and pollinator insect visitors of 74 ornamental plants. This study found variable visitation in both native and ornamental plant species but did not conclude discernable patterns to specifically attractive plants. Two studies comparing cultivars native and non-native to Great Britain (Comba et al., 1999a; Comba et al., 1999b) used insect and nectar measurements to assess the capability of plants to provide for pollinators. They found plants producing more nectar were generally less culturally modified and received more insects. Garbuzov & Ratnieks (2014) used insect and flower measurements with 32 ornamental species to potentially connect plant attractiveness to insect visitation. This project did not find a pattern of attractiveness that suggested either native or nonnative plants were superior in insect attraction, but both groups had specimens which attracted significantly more pollinators than others.

A limited number of studies have compared pollinator support of native species and their cultivars. A study done at Mt. Cuba observed the pollinators of *Coreopsis* hybrid cultivars and

determined that the four cultivars studied differed in visitation (Troy, 2013). *Coreopsis* ‘Fruit Punch’ had the highest counts across three weeks and difference was speculated to be driven by the differences in floral and vegetative morphology. White (2015) at the University of Vermont compared 12 native herbaceous perennial species to one cultivar per species. Half of the cultivars were equally supportive of pollinators as their straight species and one cultivar, *Veronicastrum virginicum* ‘Lavendulterm’, attracted more pollinators than the straight species. It was concluded that cultivars that had similar flower morphology to the straight species had equivalent pollinator attractiveness. Interspecific hybrids and greatly modified cultivars were less comparable to the original species in pollinator visitation. Using nectar measurements, it was also determined that two cultivars of *Lobelia cardinalis* were not equivalent to the straight species with respect to nectar volume or sugar concentration. A preliminary study by Poythress and Affolter (2014) compared the native species of *Coreopsis grandiflora* and *Oenothera fruticosa* and their cultivars *C. grandiflora* ‘Tequila Sunrise’ and *O. fruticosa* ‘Cold Crick’. This was a one-day analysis consisting of repeated sampling using a vacuum sampling method to capture insect foragers. They found that both cultivars had higher insect diversity than the species, but *O. fruticosa* ‘Cold Crick’ attracted more insects than the straight species, while *C. grandiflora* ‘Tequila Sunrise’ attracted less insects than the straight species.

Study Native Species

My project will evaluate six native shrubs species and one or more of cultivars of each for insect pollinator support. The native shrubs species are: *Aronia melanocarpa* (Michx.) Elliot, *Clethra alnifolia* (L.), *Potentilla fruticosa* (L.) Rydb., *Kalmia latifolia* (L.), *Physocarpus opulifolius* (L.) Maxim., *Hydrangea arborescens* (L.). Most of these species and their cultivars

are common within the nursery trade and the landscape. Cultivars of these species have been selected for differences in plant habit, form, flower color, leaf color, and bloom duration.

Aronia melanocarpa

Aronia melanocarpa is a member of the Rosaceae family. This plant is both an ornamental and nutraceutical crop. *A. melanocarpa* ranges from Newfoundland south to Georgia and west to Minnesota and Arkansas. *A. melanocarpa* most commonly occupies wetland type environments, but are adapted to drier sites like thickets, dunes, or rocky slopes (Hightshoe, 1988). *A. melanocarpa* can grow to 1 to 2 meters in height and can form suckering patches in the landscape (Dirr, 1998; Leonard, 2011). Alternate leaves are obovate, glossy, and dark green. Stems are smooth, slender, and brown. Individual flowers are small (2.5-4cm) and white and from 8 to 12 cm long corymbs. Bloom period starts in early May and ends in late May (Hightshoe, 1988; Dirr, 1998). *A. melanocarpa* supplies fruit for winter foraging birds. Cultivars with increased fruit production and compact habit have been selected for fruit and nursery production, respectively. Hardin (1973) states that *A. melanocarpa* flowers are used by “various insects” and that *A. melanocarpa* is likely pollinated by small bees like species in Andrenidae.

Clethra alnifolia

Clethra alnifolia is a member of the Clethraceae family. This deciduous shrub is typically found in locations with access to water like the edges of lakes, streams, and bogs. *C. alnifolia* ranges that extends from east Texas along the coast north to Maine. *C. alnifolia* has a round to obovoid shape and moderately dense foliage. Dark green, obovate to oblong and glossy foliage emerges in May. Leaves are alternate on pubescent gray-brown stems. *C. alnifolia* forms 5 to 15

cm long panicles with perfect, white, and fragrant flowers. Bloom period starts in late June or early July and ends in August.

C. alnifolia is a popular forage plant for many types of bees. It is also a popular native shrub for landscapes due to its attractive flower and form. There are several cultivars available in the nursery trade. Reed (2006) cytologically examined *C. alnifolia* 'Hokie Pink' and concluded that *C. alnifolia* may be an autotetraploid or an allopolyploid. In a later study, Reed (2006) found differences in seed set and viability among *C. alnifolia* cultivars which reflected variation in chromosome number. This study proposed that the variable number of chromosomes may have caused these changes.

Hydrangea arborescens

A common native shrub sold in nurseries is *Hydrangea arborescens*. *H. arborescens* is a member of the Hydrangeaceae family. Wild Hydrangeas typically grow in partly shaded, steeply sloped and open wooded areas. It is adaptable in many landscapes. *H. arborescens* range stretches from Florida to New York, and west to Oklahoma. Wild *H. arborescens* populations mostly propagate themselves through vegetative stolons and form dense clonal patches. The dull, medium-green leaves of *H. arborescens* are simple, opposite, dull medium-green, and oval to elliptically shaped. This species produces white corymbs, 10-15cm in diameter that are comprised of fertile and sterile flowers. Bloom period is from early June to late July. Robertson (1892) noted that blooms attract species from 12 families of insects, many of which were pollinators. In a flower visitation study, Palitowski (1980) recorded 52 insect families, and postulated that *H. arborescens* inflorescence form may influence pollinator attraction.

Kalmia latifolia

Kalmia latifolia, a member of the Ericaceae family, is a well-known plant in the nursery trade. In its native range, from Maine to Louisiana, it is most commonly found in woodland edges or forests and plants in the landscape benefit from part shade (Hightshoe, 1988). *K. latifolia* forms mounded colonies in the wild, but in the landscape it tends to retain a more compact shape. Evergreen foliage is alternate, dark green and glabrous (Dirr, 1998). *K. latifolia* is known for its picturesque branching pattern and white flowers in 10-15 cm diameter corymbs that bloom from early-mid June to late June (Hightshoe, 1988; Dirr, 1998). Flowers are perfect and have unique anthers, which rest in cavities within the petals until released by touch (Dirr, 1998). When triggered the anthers move outward, depositing pollen on insects or into the wind. Real and Rathcke (1991), found that nectar secretion in *K. latifolia* insect visitation were positively correlated. They also found that plant attractiveness to insect pollinators specimens varied by season. Individual *Kalmia* flowers vary in longevity based on whether pollination has occurred and can remain functional for 21 days if unpollinated (Rathcke, 2003).

Physocarpus opulifolius

Physocarpus opulifolius, commonly called eastern ninebark, is a member of the Rosaceae family. This plant is native from Newfoundland, Canada south to Florida and west to Missouri and North Dakota. Native habitat consists of stream or riverbanks with sandy soils. In most landscapes it prefers full sun. *P. opulifolius* is an upright spreading shrub with a dense rounded form in full leaf. Plants appear as a ragged mass of stems in the winter. Plants have 3 to 5 lobed, medium green leaves that alternate along angular, exfoliating, and orange to brown stems. Flowers are a white or pinkish and produced in 2.5-5cm diameter corymbs that bloom from May to June. *P. opulifolius* has shown pollinator support potential in a study by Jabłoński and Kołtowksi (2004) where nectar secretion abundance was measured. *P. opulifolius* had a nectar

secretion rate of 4 to 5mg of sugar Based on an average of 10 flowers per plant. A six-year study recorded insect attraction and use of *P. opulifolius* leaves and flowers by insect species. It was reported that 24 phytophagous families (excluding the inflorescence) used *P. opulifolius* and 34 families utilized the inflorescences (Wheeler Jr. & Hoebeke, 1985). This study mentioned that species numbers of Andrenidae and Syrphidae species were particularly abundant.

Dasiphora fruticosa

Dasiphora fruticosa, commonly called potentilla, is a member of the Rosaceae family. This plant has a wide native range spanning across the Northern Hemisphere (Elkington & Woodell, 1963). Native habitat can range from dry rocky outcrops to river edges. Plants prefer an open, sunny, wet or dry location. *D. fruticosa* can tolerate extreme cold and salt exposure (Hightshoe, 1988; Dirr, 1998). *D. fruticosa* has a low (30-120cm in height), rounded. The alternate, pinnately compound leaves are a blue-green above and silvery pubescent below. Terminal yellow flowers in cymes or solitary bloom from early June until frost (Dirr, 1998). Bloom usually consists of two peak periods, with the later period being more robust (Elkington & Woodell, 1963). Iberian populations of *Dasiphora* spp. were observed for pollinating forces to better describe the reproductive biology of this genus (Guillén et al., 2005). This report found that Mediterranean populations of *D. fruticosa* were mainly pollinated by many species of Apoidea, Syrphidae, Lepidoptera, and Hemiptera.

Measuring Pollinator Support

Measurements of insects can be done several ways. Visual or physical counts are often used to quantify insects attracted to a plant but require the investigator to judge if the insect is using the plant. Foraging behaviors such as probing, grooming, or feeding are indicators that are

frequently used to determine plant use (Garbuzov & Ratnieks, 2014; Hanley et al., 2014; Harmon-Threatt & Kremen, 2015). Number of visual observations, duration between observations and duration of actual observations are important factors to consider when recording insects. Observation periods can vary from three seconds (Harris et al., 2016) to five minutes (Comba et al., 1999a), but are performed based on the size and number of observable plots. In field observations of pollinators can vary based on location and insects available in a location, but generally coincides with environments conducive to foraging (Heinrich, 1975; Waddington, 1983; Comba et al., 1999b). Locations or time periods where temperatures are too low or high usually permits less visitation by insects (Heinrich, 1975; Bell, 1990). These conditions are likely the reason most insect visitation observation studies occur during 0900 hours to 1600 hours due to the appropriate temperatures and generally coincides with forage availability. Visual identification can be challenging, but sampling can be used to capture unknown specimens if needed (Comba et al., 1999b). Physical sampling of insects by vacuuming or netting is another way to measure insect activity (Poythress & Affolter, 2014; Harris et al., 2016). When periodic sampling is used, the assessor should take care not to destroy or damage the plants. Sweep netting and vacuuming does allow micro or smaller insects not able to be visually accounted for into measurements, unlike visual counts which are based mainly on insects observable by eye.

Floral Morphology

Many different flower traits and characteristics facilitate interactions between pollinator and plant for the purpose of fertilization. Plant flower color, shape, size, and height play important roles in attraction. For foraging pollinators, these traits help insects locate and assess their food sources. In general pollinator species have preferences that impact the selection of

their flowers of choice. Pollinators are usually attracted by floral color, and size (Waddington, 1983; Kearns & Inouye, 1993; Crawley, 1997; Howe & Wesley, 1997), but use nectar, and pollen to determine the quality of their forage (Hanley et al., 2008; Russel et al., 2015; Vaudo et al., 2015). Pollinators like honeybees (*Apis mellifera*) and bumblebees have also been known to forage differently based on different stressors or pathogens that impact foraging behaviors (Gegear et al., 2006; Goulson et al., 2015).

Floral measurements used to describe pollinator attraction or benefit has been conducted in several studies (Comba et al., 1999a; Spaethe et al., 2001; Tuell et al., 2008; Garbuzov & Ratnieks, 2014; Hicks et al., 2016; Reverté et al., 2016). The following will be an examination of these studies to show potential advantages or outcomes of floral measurements. An experiment by Spaethe et al. (2001) found that *Bombus terrestris* was affected by the color contrast of flowers and leaves, as well as inflorescence size. Bumblebees that encountered flowers with greater contrast and size had significantly lower search times. Corolla length, plant area and bloom scores were measured by Garbuzov & Ratnieks (2014) to find potential significance factors related to insect visitation. In many cases, bloom intensity and corolla length were found statistically significant for all nine of their insect groups. In a study with flower color and its characteristics (Reverté et al., 2016), spectrometry was used to find specific flower reflectance spectra of 85 plant species. Combined with insect survey measurements, they demonstrated that regular associations of colors and insect pollinator groups were found. Comba et al. (1999a) measured cultivar flower shape, size, parts, color, and density to determine if horticultural modifications significantly affected nectar secretion or insect visitation. This study found most specimens with higher levels of modification had lower insect visitation and nectar standing crops. A study conducted in four cities in the United Kingdom measured floral abundance,

density, and longevity of two seed mixes and weeds found a correlation with floral characteristics and floral resources (Hicks et al., 2016). Findings showed pollen volume and nectar sugar mass were related to by unit area to flower count. Another study by Tuell et al. (2008) had similar findings using floral area measurements and found that higher densities of flowers attracted wilder bee pollinators.

Foraging Behavior

Plant-insect interactions are dynamic and require knowledge of what drivers motivate them. Broadly speaking, insect pollinator behavior is influenced by resources, sensory information, or competition (Waddington, 1983; Kevan & Baker, 1983; Howe & Westley, 1997). The following will be a general overview of preferences and drivers of pollinators mainly focusing on Hymenoptera: Anthophila. Pollinator group's foraging behaviors will be loosely based on pollinator syndromes (Waser, 1983), but will include other studies which describe other or similarly observed preferences (Mitchell et al., 2009). Many factors are thought to interact and shape foraging pollinator behavior, and floral rewards like nectar or pollen are among them (Stephenson & Bertin, 1983). For instance, flowers that attract pollinators of particular groups or taxa, are thought to cater to them with specific sugars, proteins, or other dietary necessities (Kevan & Baker, 1983; Howe & Westley, 1997). This has been supported by studies that find groups of pollinators with apparent preferences in these resources (Mevi-Schultz & Erhardt, 2005; Abrahamczyk et al., 2017; Vaudo et al., 2015; Vaudo et al., 2016a; Vaudo et al., 2016b). Butterflies and moths (Lepidoptera) prefer nectar with sucrose and amino acids (Baker & Baker, 1990) and "less viscous" nectar (Kevan & Baker, 1983). Butterflies were seen to prefer nectar with amino acids over nectar without (Mevi-Schütz & Erhardt, 2005), and if females that foraged nectar with amino acids they produced more eggs. Abrahamczyk et al. (2017) found variation in

floral nectar sucrose proportions and the pollinator groups attributed to them. This study found flowers attractive to generalist pollinators (small bees, butterflies, and wasps) were lower in total sucrose compared to flowers attractive to specialists which offered more sucrose. They also found overlap within pollinator groups like butterflies, specialized flies, and bee and wasps, which proportionally have greater sucrose concentration flower affinities. Many studies have looked at *Bombus* sp. and *Apis mellifera* diets and foraging preferences regarding nectar and pollen. Bees exact nutritional needs are not known, but it is well known that bees attempt to regulate their diets across different available floral resources (Vaudo et al. 2015). In a study by Vaudo et al. (2016a) *Bombus impatiens* specimens were placed in an environment with plants with pollen of varying protein:lipid ratios and received minimal environmental and floral cues. This experiment found that bees foraged pollen with greater pollen:lipid ratios at an exponential rate. In a further experiment, it was found that ratios of 5:1 and 10:1 received the greatest number of bumblebee visitors while even greater concentrations of nutritious pollen received less foragers. In a later study it was confirmed by a different experiment (Vaudo et al., 2016b) that both *Bombus terrestris* and *Bombus impatiens* selectively regulated their pollen diets according to their nutritional needs. Nectar is similarly selected by bees for nutrients like sugar, but there currently stands a division in the interpretation of early nectar-bee studies (Vaudo et al., 2015). Other factors like flower color preference, shape, and size play important roles in pollinator preferences.

Beetles (Coleoptera) are characterized by their “messy” and “primitive” means of pollination, but many species are known foragers of floral parts or prey on other insects within flowers (Kevan & Baker, 1983). Most beetle pollinator syndrome characterizations include flowers that are open, bowl or flat shaped, but otherwise variable in appearance (Howe

&Westley, 1997). Flies (Diptera) also commonly pollinate flowers and in many pollinator studies, represent a large proportion of insect visitors (Comba et al., 1999b; Garbuzov & Ratnieks, 2014; Orford et al., 2015). Flies usually forage white or yellow flowers, but associations to flowers that attract flies based on carrion-like appearances are also common (Kevan & Baker, 1983; Howe & Westley, 1997). In general butterflies prefer large flowers with vibrant colors and long corollas. Moth flowers tend to be large, white or yellow colored, and strongly scented.

Nectar

Nectar is an important food source for insect pollinators like butterflies, moths, bees, and syrphid flies. The plant provides the pollinator sugars and carbohydrates in the nectar, and in return the pollinator facilitates pollen spread and pollination. Dynamics of the plant and pollinator relationship vary depending on the species involved. Nectar measurements have been used to study this relationship (Baker & Baker, 1990), and how pollinators benefit from foraging plants in the landscape (Comba et al., 1999b).

Removal of floral nectar is a difficult procedure that is impacted by biotic and abiotic factors (Schweiger et al., 2010). For example, *Kalmia* plants situated in shade showed reduced nectar and less pollination (Rathcke, 1988). Plant nectar production is often studied by measuring nectar secretion rates, which is the rate at which flowers are secreting nectar evaluated through periodic extraction of nectar from flowers. Kearns and Inouye (1993) and Corbet (2003) outline many methods of nectar extraction depending on available resources. Implements like microcapillary tubes and syringes may be used to extract nectar. Microcapillary tubes should be handled precisely to avoid damaging the flower and to prevent extraction from unwanted floral tissues that can skew the measurements. Nectar is extremely difficult to extract from flowers

with low nectar volumes or concentrated viscous nectar. Using a suction bulb at the end of the microcapillary or adding a known volume of distilled water to the nectary may be used in these situations. When a known volume of nectar can be taken it allows for measurements of sugar concentration, nectar standing crop, and secretion rate. Solute or sugar concentrations may vary depending on the microenvironment of the flower and reabsorption of water or sugar by the flower in response to ambient humidity. The sugar concentration of nectar secreted can vary at different time of the day (Cruden & Hermann, 1983; Corbet, 2003). Nectar measured with a refractometer will give a measure of percent sucrose. Sugar content can then be calculated if the volume of nectar extracted can be measured (Cruden & Hermann, 1983; Corbet, 2003).

Kearns and Inouye (1993) and Corbet (2003) have highlighted wicks as another method of sampling nectar that is highly viscous or of low in volume. Filter paper wicks are unlikely to damage flowers and through photochemical analysis can measure sugar content but cannot measure volume. McKenna and Thomson (1988) utilized Whatman Number 1 filter wicks to collect samples (<1 μ L), removed the sugars using the anthrone method (Umbreit et al., 1972), used spectrophotometry to measure carbohydrates. Ashman and Stanton (1991) working with *Sidalcea oregana* used microsyringes to add 2 μ L of distilled water to small quantities (unspecified) of nectar to retrieve with wicks and repeated with another 1 μ L of distilled water. Comba et al. (1999b) compared nectar secretion rates and nectar standing crops of nonnatives and natives of Britain to ascertain their potential benefits to supporting local pollinators. They used microcapillary tubes to extract nectar from the base of the flower and measured the fluid volume by the length of the tube. Extracted nectar was then placed on a refractometer to calculate the solute concentration of sugars within the sample. This study established that nectar rich species that were abundant with insects have potential to provide adequate forage for

pollinators. For instance, *Saponaria officinalis* had high counts for *Apis mellifera* L. (87) and a standing crop of 0.5mg sugar per flower, compared to *Dipsacus fullonum*, which attracted no *Apis* and high amounts syrphid flies (100+; Syrphidae) with a peak standing crop of 0.005 mg sugar per flower.

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Chapter Two: Nativar Insect Visitation Study

Abstract

There is increased interest in native plants for landscaping to support pollinators. The majority of native plants sold by nurseries are cultivars. Some consumer and conservation groups question the suitability of native cultivars to support pollinators. This work evaluated insect pollinator visitation for six native shrub species, and one or more cultivars of each species. The following species were installed in a full sun field behind the University of Connecticut Floriculture Greenhouse Facility in a randomized complete block design with three replicates: *Aronia melanocarpa*, *A. melanocarpa* ‘UCONNAM012’ Ground Hog®, *A. melanocarpa* ‘UCONNAM165’ Low Scape Mound®, *Clethra alnifolia*, *C. alnifolia* ‘Hummingbird’, *C. alnifolia* ‘Ruby Spice’, *Dasiphora fruticosa*, *D. fruticosa* ‘Goldfinger’, *D. fruticosa* ‘Pink Beauty’, *Hydrangea arborescens*, *H. arborescens* ‘Annabelle’, *Kalmia latifolia* *K. latifolia* ‘Sarah’, *Physocarpus opulifolius*, and *P. opulifolius* ‘Monlo’ Diabolo®. For each plant in 2017 and 2018 insect visitation was measured on ten different occasions during the bloom period using visual observation with each observation period lasting 5 minutes. Insects were identified to the following 12 categories: *Apis mellifera*, *Bombus* spp., Andrenidae, Halictidae, Megachilidae, other bees, Lepidoptera, Syrphidae, other flies, wasps, Coleoptera, and other insects. Data was collected on plant and inflorescence size. Insect visitation was similar for *C. alnifolia* and its cultivars and *K. latifolia* and its cultivar. *A. melanocarpa* had more Andrenid visitors than both of its cultivars, which was not unexpected since *A. melanocarpa* was significantly taller than the cultivars and produced more inflorescences. Floral densities were the same on *A. melanocarpa* and its cultivars, so the cultivars are not less attractive to pollinators, but their smaller size limits the number of visitors. *D. fruticosa* had more visitors of *Bombus* spp.

and Megachilidae than both of its cultivars. These insects may have been less attracted to ‘Pink Beauty’ due to its pink flower color and ‘Goldfinger’ due to its wider flowers, which result from it being a tetraploid. *H. arborescens* ‘Annabelle’ had fewer visitors of *Bombus* spp. and Halictidae than *H. arborescens*, because ‘Annabelle’ flowers consist of 58% sterile florets, compared to the 1% sterile florets for the straight species. Syrphids preferred *P. opulifolius* ‘Monlo’ to *P. opulifolius*, possibly because white flowers contrasted more strongly with the reddish purple foliage of ‘Monlo’ compared to the green foliage of the straight species. These findings indicate that cultivars are not universally less or more attractive to pollinators and must be evaluated on a case-by-case basis.

Introduction

Insect pollinators provide valuable ecosystem services, but pollinator populations and diversity are declining (Potts et al., 2010). Pollinator conservation efforts encourage the development of native plant habitat to provide insect forage and shelter (Vaudo et al., 2015; Potts et al., 2016). Consumer demand for native plants for landscaping to support pollinators has increased. It has been suggested that straight species of native plants are preferable to native plant cultivars for supporting pollinators, but this has not been scientifically proven (Becker, 2015; Botts, 2014). Nurseries producing landscape plants typically grow cultivars. There have been a few insect pollinator visitation studies conducted for herbaceous perennial species and cultivars (Garbuzov & Ratnieks, 2014; Poythress & Affolter, 2014; Harmon-Threatt & Kremen, 2015; Harris et al., 2016). White (2016) conducted research for her doctoral dissertation evaluating pollinator visitation between native species and cultivar for several herbaceous perennial species. My research evaluated pollinator visitation for six native shrub species and one or more cultivars of each species. If the cultivars are equivalent to the straight species at

attracting pollinators, they can be used to develop pollinator habitat. Simultaneously, nursery producers will realize a new market for native shrubs and pollinator decline may cease.

Experimental Design and Materials and Methods

In 2015, a research planting containing six native shrub species and one or two cultivars of each species for a total of 15 distinct genotypes (Table 3), was established in an outdoor planting field behind the Plant Science Floriculture Greenhouse Facility in Storrs, CT (41.812643, -72.252741). The experimental unit was a single plant and the planting was arranged as a randomized complete block design with three replications (45 plants total). Plants occupied five planting rows (16.5 meters long and 1.2 meters wide) with nine plants per row. Plants were spaced 1.8 meters apart within rows and rows were 1.2 meters apart. Study plants were obtained from nurseries, collected from the wild, or donated (Table 3). Drip tape irrigation was installed in spring of 2017. The length of irrigation tape was 182.2 meters. It began at the short edge of the first row and ran down to the opposite end, then continued into the following rows and followed in the fashion to the end of the planting. Between emitter spacing was 45.7 centimeters, and there were approximately 398 emitters in the planting. During the growing season, irrigation was run twice daily for 15-minutes each period. Each plant had four emitters centered at the root zone and received 2.7 L of water per day. Three levels of fencing were used to exclude animals from browsing and damaging research plants. A three meter tall nylon netted post fence with a gate was installed around the perimeter of the planting in 2015. In 2016, a one meter tall, 16-gauge wire mesh fence was installed just outside of the nylon fence, which extended around the perimeter of the planting except for the gate. This fence was installed with the lower one-third of fence below ground and the upper two-thirds above ground. In 2017, a 1.2 meters tall wire

fencing was installed just outside the existing fencing and around its perimeter including the gate. In 2016, prior to the installation of the third fencing barrier, plants of *Aronia melanocarpa* suffered heavy rodent damage and study plants lost many shoots, containing flower buds. With the added fencing in 2017 plants recovered well and insect visitation data could be collected in 2018. In April and July of 2017 and 2018, plants were fertilized with 30 g of granular 15-15-15 (Loveland Products, Loveland, CO) in the area 30 cm to 60 cm from the crown. The soil at the research planting has a 5.3 pH and 9.5 meq/100g cation exchange capacity.

In 2017 and 2018 data were collected on plant width and height, number of inflorescences per plant, inflorescence height and width, and number of flowers per inflorescence. Plant height and width measurements were made after full leaf expansion. Plant width and inflorescence width was measured twice, at right angles to each measurement, and averaged. Similarly, inflorescence widths were measured twice and averaged for three inflorescences. Number of flowers per inflorescence and inflorescence height and width were measured for three randomly selected inflorescences per plant and averaged. The duration of bloom and peak bloom were recorded (Figure 1). Plant size (volume) was the product of height and two widths. For *Dasiphora fruticosa* and *Physocarpus opulifolius* genotypes the number of inflorescences was counted for a quarter section of a plant, selected at random. Floral density was calculated by dividing the number of inflorescences by plant size. The data from 2017 and 2018 were combined, and year was treated as a random effect. Plant measurement data were subjected to analysis of variance (Procedure Glimmix) and mean separation was done for genotypes of the same species using Tukey's honestly significant difference test ($P \leq 0.05$) using SAS (version 9.4 for Windows; SAS Institute, Cary, NC).

Insect visitation data were collected during the bloom period for each plant. The number and classification of insects was accomplished using visual identification. For each plant, insect visitation was observed and quantified on ten separate occasions with each observation period lasting 5 minutes. Observations were made from approximately one meter from the plant. During observation periods, movement and noise were kept to a minimum. In general, two observations (one in the morning and one in the afternoon) were made per suitable counting day. Suitable counting days had temperatures above 17.8° C, wind speeds less than 13 kilometers per hour, and mostly cloudless skies. Observations were made during the optimal daily insect visitation time frame of 0930 hours to 1630 hours (Garbuzov & Ratnieks, 2014; Goulson & Darvill, 2004; Gillespie et al., 2017). Temperature, humidity and light intensity at the research planting was monitored using a mini weather station (WatchDog 2475 Spectrum Technologies Inc.). For *Aronia melanocarpa*, *Kalmia latifolia* and *Physocarpus opulifolius* and their cultivars, which exhibit bloom times lasting one to two weeks, four to six insect observations were made per week per plant. For *Clethra alnifolia*, *Hydrangea arborescens*, and *Dasiphora fruticosa* and their cultivars, which bloom for five weeks or more, two insect observations were made per plant per week. Insects were identified to the following 12 categories: *Apis mellifera*, *Bombus* spp., Andrenidae, Halictidae, Megachilidae, other bees, Lepidoptera, Syrphidae, other flies, wasps, Coleoptera, and other insects. Hymenoptera were identified to family and species level, and Diptera were identified to family level. For each plant, insect counts for the 10 observations were summed within each insect category. The data from 2017 and 2018 were combined, and year was treated as a random effect. Insect data were subjected to analysis of variance (Procedure Glimmix) and mean separation was done for genotypes of the same species using Fisher's

honestly significant difference test ($P \leq 0.05$) using SAS (version 9.4 for Windows; SAS Institute, Cary, NC).

Results and Discussion

For *Aronia melanocarpa* and its cultivars ‘UCONNAM165’ and ‘UCONNAM012’, the primary pollinator visitors were bees from the family Andrenidae (Table 1). Additional important insect categories were other bees, other flies, and other insects. Significantly more andrenids visited *A. melanocarpa* than its cultivars ‘UCONNAM165’ and ‘UCONNAM012’. Hardin (1973) reported andrenids as potential pollinators of *A. melanocarpa* and observed ant (Family: Formicidae) and fly visitors for this species. Flowers opened about one week earlier for the *A. melanocarpa* cultivars than for the straight species, but the duration of bloom was similar for all three genotypes (Figure 1). As expected, *A. melanocarpa* was taller than both of its cultivars, and ‘UCONNAM165’ was taller than ‘UCONNAM012’ (Table 2). *A. melanocarpa* had significantly more inflorescences than ‘UCONNAM165’ and ‘UCONNAM012’. To understand how the significant change in height between *A. melanocarpa* and ‘UCONNAM012’ impacts pollinator attraction, we can for each plant divide the number of andrenids by the number of inflorescences, and compare the quotient, which for these plants was equivalent at 0.2. This indicates that the compact cultivar ‘UCONNAM012’ does not appear to be less attractive to pollinators than *A. melanocarpa*, but its smaller size may limit the number of inflorescences and insect visitors. *Lavandula* hybrid plants, which had taller inflorescences, were preferred over wither parental species, which had shorter inflorescences, suggesting bees gravitated towards inflorescences that were more prominent (Garbuzov and Ratnieks, 2014). ‘UCONNAM012’ is utilized in the landscape differently than the straight species *A. melanocarpa*. ‘UCONNAM012’ would be used in large numbers of plants to develop a groundcover or mass planting, whereas

use of *A. melanocarpa* is typically limited to a small group or a single specimen planting due to its larger stature. A group planting of 12 ‘UCONNAM012’ plants that matched the area of a planting of *A. melanocarpa* would have similar or greater pollinator visitation. ‘UCONNAM012’ had significantly more visitors of other insects than *A. melanocarpa* (Table 1). Within *Aronia* other insects consisted of mostly ants, which are ground dwelling insects that probably found it easier to access inflorescences on the shorter plants of ‘UCONNAM012’ and ‘UCONNAM165’ than the taller plants of *A. melanocarpa*. Twice as many other bees visited ‘UCONNAM012’ and ‘UCONNAM165’ than *A. melanocarpa*, but this finding was not statistically significant (Table 1). There were no significant differences between *Aronia* genotypes for the remaining insect categories.

There were no significant differences in insect visitation for all insect categories between *Clethra alnifolia* and its cultivars, ‘Hummingbird’ and ‘Ruby Spice’ (Table 1). Change in floral color from white (*C. alnifolia* and cultivar ‘Hummingbird’) to pink (*C. alnifolia* ‘Ruby Spice’) did not impact pollinator visitation. Similar findings with *Lavandula* species and cultivars, where flower colors ranged from white to pink to blue, showed that flower color did not impact bee attraction (Garbuzov and Ratnieks, 2014). Most insect visitors ($\geq 80\%$) for *Clethra alnifolia* and its cultivars were *Bombus* spp. Additional important insect categories were *Apis mellifera*, other bees, Lepidoptera and wasps. Although not statistically compared, it is worth noting that *C. alnifolia* and its cultivars had more Lepidopteran visitors than any other species in the study. *C. alnifolia* and its cultivars also had more visitors of *Apis mellifera* than any other species except for *Physocarpus opulifolius* and its cultivar ‘Monlo’. *Bombus impatiens* and *Apis mellifera* were determined to be frequent visitors of *C. alnifolia* in work conducted at the University of Connecticut by Heminson (1985). Ongoing research at the University of Kentucky to assess bee

visitation on woody ornamental landscape plants found that for *C. alnifolia* 39.5% of bee visitors were of the species *Bombus* and 46% were halictids (Mach 2018). The University of Kentucky researchers in their list of 40 bee friendly woody ornamentals for landscapes rated bee visitation for *C. alnifolia* to be “very heavy”, which was the highest visitation rating given (Mach 2018). As expected, *C. alnifolia* ‘Hummingbird’ was significantly shorter and smaller in size than the straight species, *C. alnifolia* (Table 2). Despite its reduced stature, *C. alnifolia* ‘Hummingbird’ produced a similar number of inflorescences as *C. alnifolia* and *C. alnifolia* ‘Ruby Spice’. Furthermore, *C. alnifolia* ‘Hummingbird’ had the greatest floral density. The bloom period for *C. alnifolia* and its cultivars lasted about two weeks (Figure 1). Flowers on *C. alnifolia* began opening about one week earlier than they did for both *C. alnifolia* cultivars. These findings suggest that *C. alnifolia* and its cultivars, ‘Hummingbird’ and ‘Ruby Spice’ do not vary in their ability to attract pollinators. These numbers may demonstrate the lack of available forage during later months compared to more bountiful periods.

Dasiphora fruticosa had significantly more visitors of *Bombus* spp. and Megachilidae than both of its cultivars, ‘Goldfinger’ and ‘Pink Beauty’ (Table 1). These insects were less attracted to *D. fruticosa* ‘Goldfinger’, because ‘Goldfinger’ is likely tetraploid, and changes to ploidy could impact pollinator visitation (Segraves & Annenberg, 2016). I suspect that Goldfinger is tetraploid since it originated from northern Europe (Holland) and *D. fruticosa* from northern Europe is tetraploid (Elkington, 1969; Miller, 2002). *D. fruticosa* ‘Pink Beauty’ and the *D. fruticosa* used in this study were derived from North American germplasm, which is diploid (Elkington, 1969; Lenz, 1995). The timing and duration of flowering was similar for *D. fruticosa* and its cultivars, ‘Goldfinger’ and ‘Pink Beauty’ (Figure 1). Additionally, *D. fruticosa* ‘Goldfinger’ had significantly wider flowers than *D. fruticosa* and *D. fruticosa* ‘Pink Beauty’

(Table 2), and increased flower size is evidence of tetraploidy (Seagraves & Thompson, 1999). *Bombus* spp. and Megachilidae visitors may have been less attracted *D. fruticosa* ‘Pink Beauty’ than the straight species, because of its pink flower color. Several reports indicate that changes in flower color can influence pollinator visitation (Comba et al. 1999; White, 2016; Gumbert, 2000). In comparing herbaceous species with a cultivar with different flower color, six out of eight cultivars with atypical flower color were visited less by some pollinators (White, 2016). For example, with *Echinacea purpurea*, bumblebees preferred the purple flowers of the straight species rather than the white flowers of the cultivar ‘White Swan’, but other insects did not demonstrate a preference. More Coleopteran visitors were found on *D. fruticosa* ‘Goldfinger’ than *D. fruticosa* ‘Pink Beauty’ (Table 1), because these insects prefer yellow flower color rather than pink flower color (Gottsberger, 1977; Waser et al., 1996; Ollerton et al., 2009; Rotenberry, 2009). Coleopterans may have been attracted more to *D. fruticosa* ‘Goldfinger’ because of its larger flowers, which offer more physical support for these insects. More coleopterans were found on *D. fruticosa* ‘Goldfinger’ than the straight species *D. fruticosa*, but this difference was not statistically significant (Table 1). After *Bombus* spp., the category, other bees had the greatest number of visitors, which included *Ceratina* spp. and *Hylaeus* spp. In a Michigan State University evaluation of 43 northeastern US native plants, *D. fruticosa* was one of only nine species studied to be described as “highly attractive” to species to wild bees (Tuell et al., 2008). Denisow et al. (2013) studied the *D. fruticosa* cultivars ‘Maanley’ and ‘Blink’ and found primarily *Bombus* spp., *Apis mellifera*, and other solitary bee visitors on these plants. In my study, *Megachile* were observed harvesting flower petals on *D. fruticosa* and *D. fruticosa* ‘Goldfinger’, likely for use as a nesting material (Wilson & Carril, 2015).

Hydrangea arborescens had three times as many visitors of *Bombus* spp. and two times as many visitors of other bees than *H. arborescens* ‘Annabelle’, but the latter was not statistically significant (Table 1). Common visitors within other bees included *Xylocopa virginica* and *Ceratina* spp. *H. arborescens* and its cultivar ‘Annabelle’ were of similar size and produced an equivalent number of inflorescences (Table 2). The onset of flowering occurred one week earlier for *H. arborescens* ‘Annabelle’ than *H. arborescens* (Figure 1). Flowering duration was about 4 weeks for *H. arborescens* ‘Annabelle’ and 3 weeks for *H. arborescens*. The inflorescence of *H. arborescens* is a lace cap, where sterile flowers form a ring around the perimeter of the inflorescence and the central flowers are fertile containing pollen and nectar. *H. arborescens* ‘Annabelle’ was selected for having large inflorescences composed of mostly sterile flowers, which are showier than the straight species (Dirr 2009). In this study, plants of *H. arborescens* ‘Annabelle’ produced significantly wider inflorescences than *H. arborescens* as expected (Table 2). Inflorescences of *H. arborescens* ‘Annabelle’ were found to consist of only 42% fertile flowers, which was significantly less than the 99% fertile flowers measured for *H. arborescens* (Appendix A). Not only did *H. arborescens* ‘Annabelle’ have fewer fertile flowers, fertile flowers were positioned below and covered by sterile flowers, which may have limited insect access, especially for *Bombus* spp., to fertile flowers. Goulson (2003) and Heinrich (1979) note that visitors of *Bombus* spp. pursue flowers with greater nectar and pollen resources, which may explain why *H. arborescens* had more *Bombus* spp. visitors than *H. arborescens* ‘Annabelle’. An additional important insect category for *Hydrangea* was other insects, which included visitors of ants, plant bugs (Family Andrenidae), and ambush bugs (subfamily Phymatinae). Significantly more halictids were found for *H. arborescens* than its cultivar ‘Annabelle’, but this was a minor

insect category for these plants (Table 1). There were no significant differences between *H. arborescens* and its cultivar ‘Annabelle’ for the remaining insect categories.

Overall few insect visitors were observed for *Kalmia latifolia* and its cultivar ‘Sarah’ (Table 1). There were approximately 2.6 total insect visits over 10 observation events made during the bloom period, which lasted about three weeks in mid-June to early July (Figure 1). The full sun study site was not optimal for *K. latifolia* and *K. latifolia* ‘Sarah’, which prefer partly shaded conditions. In the wild plants inhabit bogs, barrens, meadows and the edge of woods, swamps and streams (Hightshoe, 1988). Plant foliage turned yellow and occasionally developed necrotic patches in year one of this study in response to the full sun conditions of the study site. The addition of supplemental irrigation to the study site in the second year, these symptoms decreased and plant performance improved. Plants grown in a more suitable site may have had increased insect visitation. However, low insect visitation was found for *K. latifolia* growing naturally in a southern Appalachian heath bald (Real & Rathcke, 1991). In this study, visitation rate averaged 1.18 insect visits per 10 min observation of 100 flowers. In my study, plants of *K. latifolia* and its cultivar ‘Sarah’ were similar in size, as expected, and produced 22 to 45 inflorescences per plant with each inflorescence consisting of about 75 flowers (Table 2).

Andrenids were the most abundant visitor for *Physocarpus opulifolius* and its cultivar ‘Monlo’ (Table 1). In a bee visitation assessment of woody ornamental landscape plants by Mach (2018) found that the majority of bee visitors at 58% were Andrenids. Additional important insect categories were other bees and Syrphidae. Andrenid and syrphid species are known to visit flowers of *P. opulifolius* (Wheeler & Hoebeke, 1985; Waldbauer, 1983). Members of Syrphidae observed on *P. opulifolius* and its cultivar ‘Monlo’ included *Temnostoma* spp., *Toxomerus* spp., and *Eristalis* spp. Significantly more syrphids visited *P. opulifolius*

'Monlo' than *P. opulifolius*. *P. opulifolius* 'Monlo' and *P. opulifolius* have similar habit and leaf and flower form, except *P. opulifolius* has green foliage and white flowers and 'Monlo' has reddish purple foliage, and flowers that are pink in bud that open to white. In this study, plants of *P. opulifolius* and its cultivar 'Monlo' were the same size and produced a similar number of inflorescences (Table 2). Plants bloomed for about two weeks in late May to early June (Figure 1). Syrphids are attracted to yellow and white flowers (Sajjad & Saeed, 2010; Shi et al., 2009) and for some flowers olfactory cues are involved in attraction (Primante & Dötterl, 2010). I don't know why *P. opulifolius* 'Monlo' was preferred by syrphids, but perhaps the white flowers contrasted more strongly with the reddish-purple foliage or there were olfactory cues provided by 'Monlo'. Although not statistically compared, it is worth noting that *P. opulifolius* and its cultivar had more *Apis mellifera* visitors than any other species in the study. *P. opulifolius* had more visitors of wasps than *P. opulifolius* 'Monlo', but wasps were a minor insect category for these plants.

Table 1. Number of pollinators visiting genotypes of *Aronia melanocarpa*, *Clethra alnifolia*, *Dasiphora fruticosa*, *Hydrangea arborescens*, *Kalmia latifolia*, *Physocarpus opulifolius*, and their cultivars for 10 five-minute observations in 2017 and 2018.

Genotype	Bees						Flies					
	Andrenidae	<i>Apis mellifera</i>	<i>Bombus</i> spp.	Halictidae	Megachilidae	Other	Other	Syrphidae	Coleoptera	Lepidoptera	Other	Wasps
<i>A. melanocarpa</i>	139.3 a ^z	0.3 a	2.7 a	0.7 a	---	24.0 a	14.7 a	4.7 a	0.7 a	---	8.3 b	1.0 a
<i>A. melanocarpa</i> 'UCONNAM165'	54.3 b	0.3 a	1.3 a	1.7 a	---	49.3 a	22.3 a	12.7 a	0 a	---	13.0 ab	0.3 a
<i>A. melanocarpa</i> 'UCONNAM012'	61.0 b	0.7 a	0.3 a	0.7 a	---	50.0 a	18.3 a	8.0 a	0.7 a	---	19.7 a	0 a
<i>C. alnifolia</i>	---	7.3 a	351.3 a	3.0 a	0.5 a	12.0 a	1.3 a	3.3 a	0.8 a	8.5 a	8.0 a	15.5 a
<i>C. alnifolia</i> 'Hummingbird'	---	8.0 a	327.5 a	0.8 a	0.2 a	9.8 a	2.3 a	2.5 a	0.8 a	8.3 a	5.7 a	12.8 a
<i>C. alnifolia</i> 'Ruby Spice'	---	3.7 a	227.7 a	1.8 a	0.2 a	8.5 a	1.8 a	3.5 a	0.3 a	10.2 a	4.8 a	16.3 a
<i>D. fruticosa</i>	0 a	2.3 a	100.5 a	3.8 a	8.2 a	38.5 a	6.0 a	10.8 a	3.8 ab	4.5 a	11.0 a	23.5 a
<i>D. fruticosa</i> 'Goldfinger'	2.8 a	3.0 a	49.7 b	6.8 a	2.3 b	42.8 a	8.2 a	19.3 a	6.3 a	3.0 a	19.2 a	24.3 a
<i>D. fruticosa</i> 'Pink Beauty'	1.2 a	0.3 a	67.8 b	8.2 a	1.2 b	35.2 a	4.3 a	13.2 a	2.2 b	2.2 a	6.8 a	9.0 a
<i>H. arborescens</i>	2.5 a	2.0 a	126.3 a	1.3 a	0.3 a	59.0 a	1.8 a	11.5 a	9.8 a	0.8 a	30.3 a	26.5 a
<i>H. arborescens</i> 'Annabelle'	0.2 a	0.8 a	38.3 b	0.2 b	0.3 a	22.0 a	1.3 a	8.8 a	13.8 a	0.2 a	31.0 a	8.3 a
<i>Kalmia latifolia</i>	0.7 a	0.3 a	0 a	---	0.7 a	---	0 a	0.3 a	---	0.3 a	0.3 a	0.3 a
<i>Kalmia latifolia</i> 'Sarah'	0 a	0 a	0.7 a	---	0.3 a	---	0.3 a	0.7 a	---	0.3 a	0 a	0 a
<i>P. opulifolius</i>	181.2 a	13.8 a	3.5 a	4.0 a	0.7 a	36.3 a	5.2 a	42.5 b	1.3 a	2.3 a	8.3 a	1.7 a
<i>P. opulifolius</i> 'Monlo'	118.0 a	9.5 a	2.8 a	1.8 a	0.3 a	26.0 a	10.7 a	63.2 a	0.3 a	1.2 a	5.0 a	0.7 b

^z Mean separation within columns, within species, indicated by different letters, by Fisher's least significant difference at $P \leq 0.05$ (n=6).

Table 2. Number of inflorescences inflorescence height and width, number of flowers per inflorescence, plant height and width, and floral density for the genotypes *Aronia melanocarpa*, *Clethra alnifolia*, *Dasiphora fruticosa*, *Hydrangea arborescens*, *Kalmia latifolia*, *Physocarpus opulifolius*, and cultivars averaged from two growth seasons (2017 and 2018).

Genotype	No. Flowers	Inflorescence	Inflorescence	No. Flowers	Plant	Plant	Plant	Floral
	or Inflorescences ^z	Ht. (cm)	Width (cm) ^x	per Inflorescence	Ht. (cm)	Width (cm) ^x	Size (10,000cm ³) ^w	Density ^y
<i>A. melanocarpa</i>	691.3 a ^v	3.7 a	3.2 a	12.8 a	137.5 a	141.6 a	287.5 a	2.4 a
<i>A. melanocarpa</i> 'UCONNAM165'	385.0 b	3.3 a	3.5 a	14.6 a	65.9 b	119.8 a	231.4 a	2.3 a
<i>A. melanocarpa</i> 'UCONNAM012'	273.7 b	3.5 a	3.5 a	14.9 a	43.1 c	127.7 a	178.7 a	1.3 a
<i>C. alnifolia</i>	389.3 a	12.9 a	2.2 a	62.3 a	138.0 a	135.3 a	241.0 a	1.4 b
<i>C. alnifolia</i> 'Hummingbird'	382.3 a	13.5 a	2.8 a	59.7 a	91.2 b	126.9 a	157.5 b	2.4 a
<i>C. alnifolia</i> 'Ruby Spice'	295.7 a	8.8 a	2.3 a	44.3 a	112.3 ab	134.6 a	209.8 ab	1.4 b
<i>D. fruticosa</i>	4125.3 a	1.9 a	2.6 b	---	84.2 a	130.5 a	153.0 a	34.0 a
<i>D. fruticosa</i> 'Goldfinger'	5304.7 a	1.5 a	3.0 a	---	78.8 a	129.4 a	140.6 a	53.0 a
<i>D. fruticosa</i> 'Pink Beauty'	4360.0 a	1.4 a	2.5 b	---	84.9 a	135.0 a	159.4 a	32.5 a
<i>H. arborescens</i>	116.5 a	6.9 a	10.3 b	644.9 a	134.5 a	176.4 a	441.5 a	0.3 a
<i>H. arborescens</i> 'Annabelle'	118.3 a	7.4 a	15.0 a	746.0 a	99.4 a	126.7 a	167.1 a	0.7 a
<i>K. latifolia</i>	45.0 a	7.7 a	8.4 a	75.7 a	71.8 a	79.0 a	48.8 a	1.0 a
<i>K. latifolia</i> 'Sarah'	22.0 a	6.2 a	6.4 a	75.3 a	74.1 a	89.8 a	75.2 a	0.4 a
<i>P. opulifolius</i>	656.0 a	4.1 a	5.2 a	73.2 a	198.0 a	265.1 a	1449.6 a	0.5 a
<i>P. opulifolius</i> 'Monlo'	702.7 a	3.5 a	4.7 a	48.0 a	191.2 a	246.5 a	1225.6 a	0.7 a

^z Number of Flowers for *D. fruticosa*, *D. fruticosa* ‘Goldfinger’, *D. fruticosa* ‘Pink Beauty’ only

^y Floral density was calculated by dividing no. inflorescences by plant size.

^x Plant size calculated using height and two perpendicular width measurements.

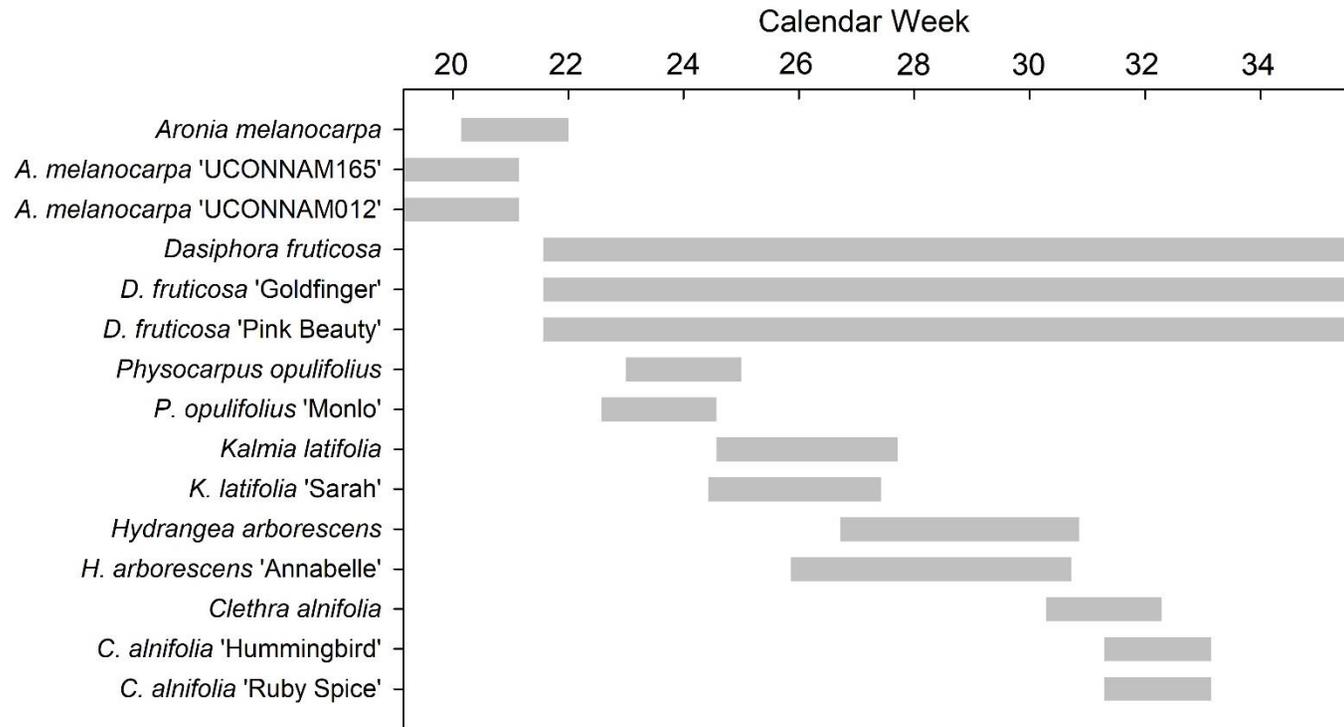
^w Width was measured twice at right angles for each measurement and averaged.

^v Mean separation within columns, within species, indicated by different letters, by Tukey’s honestly significant difference at $P \leq 0.05$ (n=6).

Table 3. Species and cultivar nomenclature, inflorescence description, plant characteristics, and plant material source of study plants

Genotype	Inflorescence	Form	Origin
<i>Aronia melanocarpa</i>	white	upright	Mark Brand, University of Connecticut
<i>A. melanocarpa</i> 'UCONNAM165'	white	low-growing; compact	Mark Brand, University of Connecticut
<i>A. melanocarpa</i> 'UCONNAM012'	white	low-growing; prostrate	Mark Brand, University of Connecticut
<i>Clethra alnifolia</i>	white	upright-tall	Pride's Corner Farms, Lebanon, Connecticut
<i>C. alnifolia</i> 'Hummingbird'	white	compact	Pride's Corner Farms, Lebanon, Connecticut
<i>C. alnifolia</i> 'Ruby Spice'	pink	upright-tall	Pride's Corner Farms, Lebanon, Connecticut
<i>Dasiphora fruticosa</i>	yellow	mounded; diploid	Wild collected, Montvale, CT
<i>D. fruticosa</i> 'Goldfinger'	yellow	mounded; tetraploid	Pride's Corner Farms, Lebanon, CT
<i>D. fruticosa</i> 'Pink Beauty'	pink	mounded; tetraploid	Pride's Corner Farms, Lebanon, CT
<i>Hydrangea arborescens</i>	white; few sterile flowers	broadly mounded	Pride's Corner Farms, Lebanon, CT
<i>H. arborescens</i> 'Annabelle'	white; many sterile flowers	broadly mounded	Pride's Corner Farms, Lebanon, CT
<i>Kalmia latifolia</i>	white	compact	American Native Plants, Perry Hall, MD
<i>K. latifolia</i> 'Sarah'	pink	compact	Pride's Corner Farms, Lebanon, CT
<i>Physocarpus opulifolius</i>	white	upright spreading; green foliage	American Native Plants, Perry Hall, MD
<i>P. opulifolius</i> 'Monlo'	pink	upright spreading; purple foliage	Pride's Corner Farms, Lebanon, CT

Figure 1. 2018 season bloom duration of study plants. Bars represent bloom time across the x-axis according to calendar weeks.



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Appendix A

	Percent Sterile Flowers	Percent Fertile Flowers
	Per Inflorescence	Per Inflorescence
<i>Hydrangea arborescens</i>	0.89%	99.11%
<i>H. arborescens</i> 'Annabelle'	57.88%	42.12%