MULTIYEAR EVALUATIONS OF ORNAMENTAL TRAITS OF THE GENUS *VITEX* AND PROPAGATION OF THE GENUS *PIERIS*

by

RYAN DANIEL MCNEILL

(Under the Direction of David Knauft)

ABSTRACT

An evaluation of segregating *Vitex* sp. seedlings was made in 2009 to compare and correlate vegetative and floral data from 2007 collected on the same genotypic population. The 2007 population included an in-ground and container treatment and the third year had only the in-ground population.

Correlations made between the first and third-year traits were greatest between vegetative traits, especially between the in-ground treatments. First year in-ground floral traits had several moderate correlations to third-year vegetative traits. Correlations between floral traits in the two years were low or non-significant except "average inflorescence length" which was moderate. First-year vegetative and third-year reproductive traits were also low. Rank comparisons between years suggest that correlations cannot offer useful predictive models on *Vitex* ornamental traits.

A study to show the efficacy of *Pieris* sp. propagation at different times of the year was conducted in 2009 and demonstrated full year rooting potential of select *Pieris* taxa.

INDEX WORDS: *Vitex agnus-castus* L., *Vitex rotundifolia* L.f., Multiyear evaluations, Propagation, *Pieris japonica* (Thunb.) D. Don ex G. Don, *Pieris phillyreifolia* (Hook.) DC

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DEDICATION

Thank you to my mother and father, brothers, and all the hedge masters throughout my life. I would especially like to dedicate this to my beautiful wife and daughter who have suffered through my writing of this thesis and the time it took me away from them.

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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

Ornamental Selection Practices

Plant breeding is a game of numbers. If a breeder wants to find a “one in a million” plant, then all he/she needs to do to is plant a million seeds (or so) and see what germinates. While this scenario is unlikely, it might be more likely to produce a novel introduction than selection from a smaller population of a few thousand seedlings.

In addition to the size of the initial screening population, a breeder must decide on additional factors concerning the future plant selection process. One factor is the environment in which the plant will be selected. The environment can include whether a plant is grown in the greenhouse or outside, in containers or in-ground, and in shade or full sun. Another factor to consider in a breeding program is the length of time a plant must be evaluated before a selection can be made.

Breeding and selection methods for ornamental plants can vary greatly depending on the crop to be produced. But whether the ornamental plant is an annual, biennial, or perennial (either herbaceous or woody), its selection will involve the same basic principle: is it demonstrably better than what is currently available? Phenotypic traits (outward appearances) are the most common traits for which ornamental breeders try to produce variability. This anecdotal conjecture has merit based on the report by S. M. Jain (2006) in which he lists the most common traits that breeders have selected for in officially released mutant varieties of ornamental and decorative plants. Over 95% of the five hundred plus traits listed are phenotypic expressions. Genotypic traits that ornamental plants may be selected for can include their ability to hybridize, sterility, or polyploidy.

Creating the variability necessary for a new ornamental plant introduction can be accomplished in several ways. Sexual recombination is the most common way to produce variation, but other ways to induce or obtain variability include the irradiation of seed or plant tissue, somaclonal mutagenesis via tissue culture or even the chance discovery of a chimera or sport. Once variation is obtained, the breeder or selector must decide which plants are not only novel but also worthy of release.

Phenotypic traits of interest to ornamental breeders can be quantified such as plant size, flowering time and duration, and number of flowers. Traits such as flower color and leaf colors, although generally considered to be qualitative traits, can also be quantitatively measured and so differentiated. All of these measures can be useful tools for a plant breeder. However, selections of ornamental plants are often based on more nebulous goals, such as ‘improved ornamental value.’ Making a selection by simply stating that a plant is “pretty” or “appealing” or better yet, “prettier” or “more appealing” can be a challenge. Rating systems are used quite extensively in ornamental plant breeding. Townsley-Brascamp and Marr (1995) employed a statistical measurement known as conjoint measurement that allowed them to measure the joint effect of two or more variables (in this case, ornamental qualities such as overall plant health, bushiness, leaf quality, etc.) on an independent variable, customer preference.

In an evaluation of ornamental crabapple varieties that took place in Ohio from August 1993 to August 2000, researchers gave an aesthetic rating for the crabapple taxa with one being the highest and five being the lowest (Draper et al., 2000). These evaluations were the culmination of several ornamental characteristics including flower, foliage, form, and fruit characteristics, and effects of disease and pest problems.

In a report by Noordegraff (2000), the Dutch Royal Horticultural Society enlists 75 to 100 consumers to test new varieties. The consumers are given new plants or flowers for free in return for filling out a questionnaire concerning their opinions of the new varieties and what cultural practices they undertake for the plants. These data from the questionnaires can not only influence what plants or flowers are marketed to the general public, but also what information to put on plant labels concerning the optimum growing conditions to give to the new variety.

The Chicago Botanic Garden (2011) maintains a plant evaluation program that serves to identify ornamental plants that are superior under growing conditions or environments in the Upper Midwest of the United States. The results of their evaluations are published online in "Plant Evaluation Notes", which is available to the public through mail order or download via the internet. In one such evaluation of *Hibiscus moscheutos* L., several cultivars and horticultural hybrids were evaluated for a number of traits including: flower color, size, form, bloom season, plant height and width, habit, leaf shape, leaf color and health, stem color and strength, and cold hardiness. All of these traits were assessed to give an overall score in the form of a three-star rating (Hawke, 1993).

***Vitex* as an Ornamental Plant**

Species in the genus *Vitex* have been used by humans for thousands of years, most notably as a medicinal plant. Only a relative few *Vitex* species (of which there are about 250 (Dirr, 1998)) may be found in American landscapes as an ornamental plant. *V. agnus-castus* L., which was introduced into America by 1570 (Rehder, 1940), is the most common species grown for its ornamental value with several cultivars that are offered by nurseries. Native to Southern Europe and Western Asia, *V. agnus-castus* has gained in popularity among gardeners (especially in the Deep South of the U.S.) and has numerous named cultivars. In addition to the four *V. agnus-castus* cultivars that served as parents in this study (‘Shoal Creek’, ‘Abbeville Blue’, Blushing Spires’, and ‘Silver Spires’) there are ‘Alba’, ‘Arnold’s Cutleaf’, ‘Colonial Blue’, ‘Fletcher Pink’, ‘Lilac Queen’, ‘Mississippi Blues’, Montrose Purple’, ‘Rosea’, ‘Snow Spire’, var. *latifolia,* and ‘Woodlander’s White’*,* (Dirr, 1998; Missouri Botanical Garden, 2011; RareFind Nursery, Inc., 2011; Metrustry and Anisko, 2006).

The ornamental value of *V. agnus-castus* is derived from its often bright purple to blue flowers that are described or compared with species of Butterfly Bush (*Buddleia davidii* Franch.). Some of the cultivars mentioned previously, however, may have white to dark pink flowers. The flowers are generally slender racemes that are then often grouped in panicles. Inflorescences vary from cultivar to cultivar with significant differences in width, length, and individual flower density observed (Dirr, 1998; Hershberger et al., 2010). Flowers occur on new growth, which can be an advantage for many cultivars which may need to be pruned yearly to control their size within a garden or landscape setting. The removal of spent flowers may also encourage new growth and re-flowering (Dirr 1998).

V. negundo L., which has late season flowers like *V. agnus-castus* (though not as large), reserves its most attractive aspect in the variety of leaf forms and their degrees of dissection. Three cultivars that are sometimes given varietal status within *V. negundo* include: ‘Cannabifolia’, ‘Heterophylla’, and ‘Incisa’ (Dirr, 1998; Metrustry and Anisko, 2006). This species was introduced in 1697 (somewhat later than *V. agnus-castus*) to North America from its native range, which includes Africa, Madagascar, and Southeastern Asia. *V. negundo* also flowers on new growth and may benefit from pruning or the removal of spent flowers to encourage new vegetative growth and flowers (Dirr, 1998).

V. trifolia L., known as the Simpleleaf Chastetree, also has purple-blue flowers and has found a home in more Southerly gardens. Its native range is from East Africa to the Pacific island of Tahiti and is most commonly found along watercourses in habitats that range from beaches and edges of mangrove swamps to inland grasslands and forests (Kew Gardens, 2011). While the flowers are certainly attractive in *V. trifolia*, the unique feature that really stands out in this species is the vivid purple underside to the gray green leaves. The leaves are especially attractive and noticeable where the wind can blow the leaves and reveal this underside coloring. Dirr (1998) reports of a cultivar 'Variegata' that has cream-edged leaves being available, and Monrovia nursery offers a variety of this plant, *V. trifolia* 'Purpurea', which it lists in its online catalog as 'Arabian Lilac' (Monrovia Nursery, 2011).

Vitex rotundifolia L.f., more familiarly known as Beach Vitex, is the most recent *Vitex* species to come to America with a date of introduction listed by the USDA as sometime in the 1980's (USDA NISIC, 2011) but as early as the 1960's by the U.S. Army's Environmental Command (Socha and Roecker, 2004). In a paper by Olsen and Bell (2005), the authors present a very nebulous and convoluted history of Beach Vitex's introduction and present evidence of its introduction to the U.S. as early as 1955 and it being introduced at least six times subsequently.

V. rotundifolia has gained a great deal of attention (albeit negative attention) as an invasive species with several articles and publications detailing its ability to quickly colonize beach dunes in the southern coastal areas of the U.S. Its rampant growth and ability to out compete native vegetation has led to the nickname "Kudzu" of the beach or coast (Socha and Roecker, 2004; Angione, 2006). Despite this fact, *V. rotundifolia* does have attractive qualities for which horticulturists prize including silvery leaves and its trailing habit which if kept in bounds by extensive pruning, can make an attractive container plant or ground cover. *V. rotundifolia* was used as a potential pollen parent in this study (all accessions with the prefix V0502). There are several previously reported interspecific hybrids of *V. agnus-castus* and *V. rotundifolia* being developed by the Chicago Botanic Garden simply listed or named "clone 1" and "clone 2" (Ault, 2004; Metrustry and Anisko, 2006).

Traits over Time

A challenge to ornamental breeders is that new cultivars must express superior attributes over time as well as in multiple environments. Many cultivars are initially propagated in greenhouses and are grown in containers that are shipped for wholesale or retail distribution. When sold, the individual purchasing the cultivar makes a decision based on the appearance of plants in containers. Particularly for woody ornamentals, the plants are then grown in-ground for a number of years. Selections of new cultivars then must perform well in containers and in-ground, and particularly once placed in-ground, must remain attractive for many years. The dilemma for breeders, then, is to determine how best to select plants that perform well in containers and in-ground, and in the latter case, over time.

Few studies have been conducted to evaluate container vs. in-ground production and the implications those treatments may have on future growth. Hershberger (Hershberger et al., 2010) conducted research into the better method of selecting ornamental traits of a segregating population of *Vitex* sp. (container or in-ground) and concluded that all flowering traits and most of the height and width measurements showed a significant genotype by environment interaction

(G x E). Because the genotypes reacted differently in each environment, she suggested that selection for traits should only occur in one environment, namely in-ground.

Few studies have evaluated ornamental plant traits over time. Just as the comparisons and correlations of discrete traits to one another can be useful for breeders in directing their programs, the comparisons of discrete traits from different years could be used to demonstrate correlations across a period of time and so be used as a predictive tool for the expression of these traits. Fruit trees such as apples, for instance, may take seven to nine years from the seedling stage to an evaluation stage (Dennis, 2003). To save time on evaluations like these, breeders need predictive tools at their disposal that may be able to save a lot in the investment of money and time.

In a paper by Callaham and Duffield (1962), Ponderosa Pine (*Pinus ponderosa* Douglas ex Lawson) seedlings were evaluated over a twenty-year period in an effort to relate seedlings' heights to their future performance (height). Although the epicotyl length measurement at 75 days was not a reliable predictor of height at 12 and 20 years, their (seedlings') heights at 5 years were. In a report by Thompson (1985), seedling diameter is reported to be the most reliable overall predictor of future growth and survivability in several pulp wood tree species. Mexal and Landis (1990) take this concept a step further in correlating seedling stem diameter to survivability and seedling height to future height. Mentioned in Thompson's paper is a study by Mullin and Svaton (1972) in which the heights of White Spruce (*Picea glauca* (Moench) Voss.) seedlings demonstrated high correlations with their respective heights at 10 years.

Examples of the use of seedling data to show or demonstrate high correlation coefficients with regards to future growth and clonal performance in ornamental plants are also reported. The selection of tulip bulbs for yields in the second year (the year after sowing seeds) was shown to have a high correlation with the fifth year yields (Horn, 2002). Horn also reports that there are high correlations found in various flowering traits in *Pelargonium hortorum* seedlings to that of their clonal replicates (2002).

Trait Correlations

New ornamental cultivars must adequately express a large number of traits, such as appropriate plant and flower size, shape and habit, leaf and flower color, pest resistance (and others). Knowledge of the correlations among these traits is important to breeders as they influence a breeder's approach to improving a plant. Traits that have a high positive correlation may be an indication of genetic linkage and so be a great advantage to plant breeders if both traits are desirable (Acquaah, 2007). Unfortunately, tight linkage would be a disadvantage if two traits were needed to be separated. Some traits like purple flower color and purple leaves in *Loropetalum chinense* (R. Br.) Oliv. var. *rubrum* Yieh (USDA GRIN, 2011) cultivars may be impossible to separate as their correlation is biologically determined, i.e. the same biochemical pathway that produces the pigment is present in all parts of the plant (including the roots). Negatively correlated traits would have the converse applications for the plant breeder. Deleterious or undesirable traits (at least together) that demonstrated negative correlations could be easily separated while two desirable traits might be more difficult to select simultaneously. It should be noted that the absence of a linear relationship between traits might not preclude any association between them at all; instead the associations may in fact be non-linear and require statistical transformation to demonstrate their relationship (Acquaah, 2007).

Another possibility is that there can be very low (negative or positive) or even no correlations between traits. The advantage of low correlations or no statistical relationships, even after transformation, is that it allows breeders the opportunity to select for combinations of traits. Carena, Hallauer, and Miranda Fihlo (1988) give an example of this with corn breeding where low correlation values are an advantage in combining traits such as high vigor and health traits with improved yields.

Research Objectives

The ability to quickly identify ornamental traits that are desirable for a new plant introduction is of great importance to plant breeders. If researchers have the ability to predict future growth characteristics (vegetative growth habits) as well as floral characteristics based on an initial (first-year) assay of these traits, then years can possibly be saved in subsequent evaluations resulting in earlier release of new cultivars. If selections of ornamental plants from an initial germplasm or population can be made in a shorter amount of time (without sacrificing a quality or stability of a trait), then valuable resources can be saved by a breeder for further evaluations on only the best stock or even for another research project.

The objectives for this research were to make comparisons of vegetative and floral characteristics measured on clonal plants from segregating populations that were evaluated on one-year plants in the ground and in containers with measurements made on three-year plants in the ground. The comparisons would then show which traits, if any, had high correlations between first-year and third-year data and so be a possible trait that could be selected early. Low correlations would also be important to note as they would mean that those traits could be selected independently from one another, or otherwise not conflict with their discrete improvement.

A second research objective was to evaluate vegetative propagation percentages in a germplasm of plants in the genus *Pieris* L. In addition to a large scale propagation study made of the entire germplasm in 2007, another propagation experiment was made on a select group of four *Pieris* taxa. This propagation study was to test whether theses four varieties could be successfully rooted (>50%) at different times of the year. Although there was literature to support the idea that different *Pieris* species could be propagated over a long period in a given year (Dirr and Heuser, 1987), there were gaps in the literature concerning year round propagation. The knowledge that plants could be propagated and cultured to a predetermined age/size throughout the year could help researchers ensure sufficient rooted cuttings for repeated experimental trials.

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CHAPTER 2

CORRELATIONS AND COMPARISONS OF MULTIYEAR EVALUATIONS OF ORNAMENTAL TRAITS OF THE GENUS *VITEX* L.

McNeill, R. D., A. J. Hershberger, and D. A. Knauft. To be submitted to the *Journal of the American Society for Horticultural Science*

Abstract

Ornamental plant breeding can take many years to produce a new salable cultivar. This is true in particular for woody ornamentals or perennials that may take several generations and a number of years to flower or express the desired traits for which breeders try to improve. There then exists the need for breeders to forecast or predict future performance of a plant through early evaluations to save time (and money) on the creation of seedling populations and their subsequent evaluations.

Vegetative and reproductive (floral) data were collected in 2009 on a segregating population of three year-old *Vitex* sp. L. seedlings planted in the field (in-ground). These data were correlated to data collected by another researcher in 2007 on the same in-ground population as well as a duplicate treatment grown in containers from two years previous (one year-old plants).

Pearson and Spearman rank analyses detailed high correlations between first year (both treatments) and third year vegetative traits. Correlations between first and third year floral traits were comparatively low, except for "average inflorescence length", which was moderate. Correlations between floral traits in the first year and third-year vegetative traits were low for containered plants but had several moderate values for in-ground plants. First year vegetative traits had low correlations to third year reproductive traits.

In addition to these correlations, data are presented whereby the top twenty accessions of various vegetative and reproductive traits from the first year in-ground and container treatments (average of the replications) are compared to the respective third year's rankings. The traits that were ranked in this manner were final height and width measurements, flower duration, total weeks of flowering, and average inflorescence length. The average ranks for the twenty

accessions in each group are given to compare the differences between the first and third years. While the average ranks for the first year's top twenty of any given trait are close to 10.5 (differences arise because of possible shared rank values which then skew the total's average), the same top twenty in the third year (container or in-ground) are comparatively much greater. All of the average ranking comparisons were lower (and therefore closer to the first year average ranks) for in-ground treatments compared with container ranks except for flowering duration.

Introduction

Multiseason and/or multiyear evaluations of ornamental traits in perennial plants are a necessary endeavor to ensure the stability of identified superior qualities, i.e. the traits are consistently expressed year after year, as a plant matures. The term multiyear, then in this instance would refer to evaluating the same plant or plants as they mature or get older. This is different than other evaluations that may be termed multiyear (or multiseason) in which plants of the same age are evaluated in different years. The evaluations in this report would fit under the former category of evaluating the same plants in successive years as they mature and get older.

Just as a grower or breeder would like to evaluate a plant's performance in different climactic zones and environments (spatial testing), he/she would also like to have temporal evaluations. Also, evaluating one trait at a time is not enough. According to Harding et al. (1991), due to the potential for correlated responses in other plant traits (possibly deleterious) "the process of selection will always be multi-trait". Determining how many years a perennial plant should be tested before a selection is released as a new cultivar is also important. Overall growth characteristics (habit), for instance, may take several years before definitive traits can be characterized. Finally, because most perennial ornamental plants are selected in containers, initially sold in them, but subsequently grown in-ground, the relation between traits expressed by a plant in a container and in-ground over time are important.

Releasing new cultivars too soon without proper evaluation can be problematic. Nakornthap (1965) reported that Canna Lily (*Canna* sp. L.) flower colors or patterns that were induced through gamma ray mutagenesis had variable stability, that is, some patterns of streaking or spotting failed to persist in later clonal replications. Other problems that may exist in releasing new introductions too soon into a marketplace can include the possibility of the plant becoming invasive in a particular environment, as with *Vitex rotundifolia*, (Socha and Roecker, 2004; Angione, 2006) or that a new plant may be a source of allergens (Hentig, 1998)

While it is then obvious that it is better to examine a potential plant introduction for many years, there is a motivation to identify marketable traits quickly, namely, economic considerations. Decisions must be made in determining how long a breeder must invest resources into a collection/germplasm before choices are made. Also, the competition from other breeders in getting their products to market makes for a difficult balance in ensuring quality and saving/making money. The ornamental plant business can be fickle and consumer trends can change from year to year. A breeder who works with the "hot" new plant from one year may find that once a new variety is developed, tested, and finally released that the market preference has changed.

Although a number of papers deal with ornamental evaluations including a number of publications through the Chicago Botanic Garden's "Plant Evaluation Notes" (2011), little information on the use of seedling or first-year plant data to correlate or predict future performance in ornamentals exists. Much of the "proof of concept" for this research came from the timber and pulp wood industry. Callaham and Duffield (1962), Mexal and Landis (1990), Mullin and Svaton (1972) and Thompson (1985) found that a number of vegetative traits in seedlings of important pulp wood species of trees (conifers) were found to be important indicators of future growth and so their economic potential for growers.

An evaluation of a collection of seedlings from the genus *Vitex* was made in order to determine if there were predictive values in data collected from a one year-old population when correlated and compared to the same genotypic population that was three years-old. Patterns in trait expressions between the two years could then be useful to plant breeders in determining which selections would be advanced for further assessment or used as potential parents for subsequent generations.

Materials and Methods

Approximately 150 accessions of *Vitex* were examined from The University of Georgia's ornamental breeding program in the summer of 2005. *Vitex rotundifolia* and four cultivated varieties (cultivars) of the species *V. agnus-castus* served as the parents for a segregating population of seedlings (Table 2.1). The seedlings were produced by pairing the female parent plants with select pollen parents in a meshed bee cage that contained a nucleus hive of honey bees (*Apis mellifera* L.) to aid in the pollination. Although *V. agnus-castus* was presumed to be able to self pollinate, that is it is self compatible, little information to support this claim except a report by Knauft (personal communication, 2011) that good seed set was obtained from *Vitex agnus-castus* flowers that were bagged and prevented from obtaining another plant's pollen. A related species, *Vitex lucens* T. Kirk was shown to be autogamous or selfing (de Kok, 2007). Assuming the same is true for *V. agnus-castus*, the lineage of the seeds was uncertain, as they could have been self-pollinated or a true cross. Approximately 3000 seedlings were evaluated from these populations, with ten percent selected for further assessment in 2007 and 2009.

Once the accessions were selected for further review, vegetative cuttings (clones) were used in the in-ground and container treatments in 2007. Each treatment contained two replications. The parents of the accessions were also vegetatively propagated and included within the two treatments and replications. This propagation ensured that each treatment (including the extant in-ground plants which provided the third-year data) contained the exact same genotypes and that any observable variations could be attributed to the environment in which they were subsequently grown and evaluated (Hershberger, 2008).

The select progeny and the parents were vegetatively propagated on 16 August 2006 by dipping terminal cuttings in a 10,000 parts per million solution of potassium indole-3-butyric acid (KIBA) rooting hormone. The cuttings were then placed in media consisting of a 3:1 Fafard 3B and perlite mixture and placed under mist in 16-cell packs for eight weeks. After successful rooting, the cuttings were potted into 3.8 L (one-gallon) containers on 14 November 2006. All plants were grown in similar fashion and received a water and liquid fertilizer regimen using 100 ppm solution of Peters Professional® 20-10-20 Peat-Lite Special® (The Scotts Company LLC 14111 Scottslawn Road Marysville, OH 43041). Half of these plants were then planted on 23 April 2007 at the University of Georgia Horticulture Research Farm in Watkinsville, GA at latitude 33° 53' 17.6028" and longitude -83° 24' 59.0436" in soil that ranged from a sandy loam to a sandy clay loam. These plants were the “in-ground” treatment in the study conducted by Hershberger in 2007. The second half of the collection was stepped up into 11.4 L (three-gallon) containers for the container treatment.

The in-ground plants were planted in five long parallel rows measuring six feet 1.83 meters (six feet) wide by 121.92 meters (400 feet) long. The rows were 3.66 meters (12 feet) apart on center with a mowed path between them. The rows were created using a chisel plow attached to a Ford 5610 tractor and repeatedly plowed until the tines reached a depth of 0.41 meters (16 inches). The coarse plowed soil was then tilled and smoothed using a Maletti box tiller attached to a Ford 2600 tractor. The tractors, chisel plow, and tiller all had an operational width of 1.83 meters (6 feet), which corresponds to the final row widths. The plants were planted in the center of these finished rows and separated within the rows by 1.5 meters (5 feet). Two weeks after planting, the planted rows received an application of ground hardwood mulch to a depth of approximately ten centimeters. Accessions were irrigated by 1.27 cm. (half-inch) plastic drip tube, which ran the length of the rows and was placed 2.5 cm (one inch) from the main stems of the plants. One drip line emitter per plant was punched into the plastic tubing and positioned approximately 7.6 cm. (three inches) from the crown of the young plants with each emitter providing 1.9 L (one half gallon) per hour. The drip system was allowed to run for 3 hours per week for the first several weeks to help establish the collection. Watering subsequent to that period was conducted at an as needed basis (Hershberger, 2008).

The containered plants were placed on a nursery pad at the Horticulture Research Farm with their three-gallon pots spaced thirty centimeters apart from their edges. The containers were watered with an overhead sprinkler system which would send out fifteen minute "pulses" as many six times per day during the hot summer months. Both the in-ground and container treatments were fertilized using Osmocote® Classic 14N-14P-14K (The Scotts Company LLC 14111 Scottslawn Road Marysville, OH 43041) on 4 June 2007. The container treatment received 44 g of fertilizer per container and the in-ground treatment was given 15.12 kg per 121.92 x 1.83 m bed.

Data collection was taken throughout each growing seasons by the respective researchers, including both vegetative and reproductive (floral) characteristics. Vegetative traits that are referenced throughout this paper are defined as height and width measurements. Reproductive or floral traits that are referenced throughout this paper include average inflorescence length, average inflorescence width, total weeks of flowering, flowering duration, first flower date and last flower date. In the initial (2007) study, height and width measurements were taken 16 May 2007, 23 Sept 2007 and 8 Dec 2007, which was after the first frost and subsequent cessation of plant growth. The 2009 study's height and width measurements were collected 7 May 2009 and 23 February 2010. It should be noted that all first year data (2007) was collected and recorded by Hershberger for her research and subsequent publications (Hershberger, 2008; Hershberger et al., 2010) while all third year data in 2009 was collected by McNeill.

Reproductive traits were measured or assessed weekly from the first appearance of petal color (not necessarily anthesis) on at least one plant until the first killing frost. The extant population for the third-year study was observed periodically in May 2009 after the collection was observed to produce the first nascent inflorescences. Once the first accessions showed any observable color in individual flowers, a weekly assessment was made over the entire collection, and each accession was given a "1" for having any floral coloring, and a "0" for having no color from a flower present.

From the binary information gathered weekly on the *Vitex* collection, a group of floral data was produced. These data included: first flower date, last flower date, flowering duration, and total recorded weeks of flowering. The first observance of flower color in 2009 began on 14

June (first flower date) and the last set of floral data was recorded 23 November 2009 (last flower date). Flower duration and total weeks of flowering would seem to be synonymous, but they differ in their respective measurements. "Total weeks of flowering" was essentially a simple sum of all the weeks the plants were in flower. Flower duration, however was a difference between the first flower date and the last recorded flower date and would not account for large gaps of time when there may have been no observable color in between (Hershberger, 2008).

Average inflorescence number (per accession) and average flowers per inflorescence were only assessed in the initial 2007 study but their data were included for comparative purposes. Inflorescence length was determined by averaging the three longest un-branched racemes on each plant. An average inflorescence width was also measured by averaging the widths of three observable widest racemes (at the base of the inflorescence). This last measurement was only made in the third-year and was taken on 21 June 2009. Average quantity of flowers on each inflorescence was rated on a scale of one to five. A value of one denoted that flowers covered up to 20%, two with 20-40%, three with 40-60%, four with 60-80%, and five with 80-100% of the inflorescences. First-year flowering data were taken weekly beginning 15 May 2007 and ending 8 Nov 2007, the date of the first frost. Third-year flowering data began 14 June 2009 and was taken weekly until 23 November 2009. The date of flower was defined as first appearance of petal color and last date of flower was defined as the date when no petal color was detected. Flower ratings for average number of flowers on the inflorescence, number of inflorescences, and inflorescence length were averaged over all weeks (Hershberger, 2008).

Data Analysis

Data were analyzed with a two way analysis of variance (ANOVA) using SAS software's General Linear Model (SAS Institute Inc., 2003). Pearson correlation coefficients were then generated and served as the basis of comparing the similarities (and dissimilarities) between the first-year container and third-year data, as well as first-year in-ground and third-year data. Correlations between third-year traits were also generated and reported. Comparisons between first-year observations were previously published (Hershberger et al., 2010). In addition to the matrix generated with the Pearson correlation coefficients, a Spearman correlation procedure was performed to demonstrate rank correlations. The Spearman correlations ranked the accessions per their respective traits in an ordinal fashion, and then correlated the accessions' position or rank in different categories. The Spearman correlation is a non-parametric measurement, that is, it does not require the assumption that the data fall into some sort of distribution (normal). It was also included to better reflect a typical ornamental selection process. Often, breeders who are looking for a particular trait in a population will select the top ten or twenty percent (for example) for further breeding efforts. If there were high Pearson correlations of a particular trait from one year to the next, but the rank correlation was significantly low, it would be worthless or a detriment to make mass a culling of the population based on an initial (first-year) rank profile because those plants that may have high rankings in subsequent years may be inadvertently thrown away.

Results and Discussion

Three distinct data sets are presented in this report. First-year container data are compared with the third-year in-ground treatment. The first-year in-ground treatment is also compared to the third-year in-ground treatment. Lastly, there are tables presented with trait correlations strictly within the third-year data. For each of the three data set comparisons, there are both Pearson and Spearman correlation analyses. Both of the correlation analyses have a range from -1 to +1, with +1 being a perfect positive linear relationship (the increase in one results in an equal increase in the other) and -1 being a perfect negative relationship (an increase in one results in a corresponding decrease in another value). A correlation value of 0 would mean that there is absolutely no statistical relationship between two variables.

First-year Container and Third-year in-ground (Pearson)

Generally low correlation values existed between vegetative data collected in the first-year containers with the third-year in-ground data (Table 2.2.1) although the vegetative to vegetative correlations between the two treatments were the highest. Trait correlations were categorized as low ($r<0.50$), moderate ($0.50\leq r<0.70$), and high ($r\geq 0.70$) (Hershberger et al., 2010). There were a few moderate correlation values between height measurements in these two treatments. The correlations with first-year (again container) vegetative measurements with reproductive data in the third-year were very low and often statistically nonsignificant.

The first-year container reproductive (flowering) data also demonstrated, on average, very low correlations with all of the third-year data (Table 2.2.2). Many values were nonsignificant or were well below the "low" threshold of $r<0.50$. The Pearson correlation value of 0.54 for average inflorescence length was the highest correlation for any two traits in the matrix of first-year container and third-year in-ground. Many ornamental breeding programs use year-old plants in containers to make initial selections from segregating populations. However, the data here suggest that there is relatively little relationship between trait expression in those plants and subsequent expression once the same plants are put in the ground and grown for several years.

First-year Container and Third-year in-ground (Spearman)

There was a general agreement in the Spearman and Pearson correlations with regards to first-year container and third-year in-ground (Tables 2.2.1-2.2.4). The vegetative traits in the two treatments had the highest correlation values but only the first-year initial height had any correlation values in the moderate range, specifically with the two third-year height measurements. As was seen with the Pearson correlation, first-year vegetative traits had very low correlation values with third-year reproductive traits and many of those were nonsignificant. These data, like the Pearson correlations are of little value in attempting to select or predict future vegetative and reproductive growth by using first-year container vegetative measurements.

First-year container reproductive correlations with third-year vegetative data were much higher (but still low) than the correlations with reproductive data in both treatments. Much of the reproductive correlation values between the two treatments were low (often with lower significance) or nonsignificant all together. The highest correlation of any first-year container and third-year in-ground traits is found between the two respective average inflorescence length measurements (r=0.55) (Table 2.2.4.)

These Pearson and Spearman correlation data indicate that breeders who have traditionally made selections of ornamental plants (or *Vitex* specifically) based on their performance in a container may be poorly predicting future growth of the plant. Any apparent vegetative trait, whether it was height or width, would have a very low correlation to the plant's future performance in the ground. This is an important determination for a plant breeder and it strongly suggests that inflorescence length in a one-year container-grown plant is the only trait that would have a good chance of carrying over or continuing in a more mature plant in a landscape.

First-year in-ground and Third-year in-ground (Pearson)

The general trend for the two in-ground treatments in this study was that the correlations between them were almost always equal to or higher than the corresponding correlations between first-year container and third-year in-ground (Tables 2.2.1 and 2.2.2). In addition, more correlation values were within the "moderate" and "high" range than with the respective container correlations. Correlations between the two treatments' vegetative measurements were much higher than first-year vegetative to third-year reproductive data as well as first-year reproductive to either third-year vegetative and reproductive data.

The low correlation values between first-year height and width with the third-year's floral data, suggest that breeders may, for instance, have difficulty in selecting floral attributes based on a plant's vegetative performance, although this scenario would be unlikely for a plant breeder. However, a plant that had a poor habit but had nice flowers can still be useful as a possible parent in a future round of breeding. The data also suggest that it may be difficult to predict future reproductive expressions based on the first-year's reproductive measurements, except for average inflorescence length, which again showed a moderate correlation between the two treatments.

The moderate correlations seen with average inflorescence length in both the container and in-ground comparisons with third-year data (and that is seen with Spearman rank correlations Table 2.2.4) help to give an indication as what environment a plant breeder should use in evaluating a *Vitex* population. Because the only floral trait that had at least a moderate correlation to itself in the third-year was average inflorescence length, a breeder should use the in-ground method of trait evaluation. The first-year in-ground correlation of average inflorescence length to the third-year average inflorescence length was very close to the container data but it was slightly higher (Table 2.2.4.). The in-ground treatment would also allow for other traits to be selected with a higher confidence as opposed to the container treatment which had low correlations for virtually all traits measured.

First-year in-ground and Third-year in-ground (Spearman)

The rank correlation values for the two in-ground treatments were very similar to their respective Pearson correlations (Tables 2.2.1-2.2.4). The greatest correlation values were seen in comparing the first-year's final height measurement with both of the third-year's height measurements as well as the first-year's final width measurement with both of the third-year's width measurements. Once again, the next highest values (as a trend) were seen in comparing third-year vegetative data to first-year floral data. The lowest values with many nonsignificant correlations were seen with the third-year's floral data compared to both the first-year's vegetative and floral traits.

These rank correlations can be a useful tool to plant breeders who may want to make broad selections in a population for inclusion or use in a future population. If the top ten percent of plants expressing a given trait were highly correlated with the top ten percent of the same population with the same trait at some future time, a breeder can have the confidence in culling the remaining ninety percent of his germplasm knowing that the trait in question will continue to be expressed in a subsequent evaluation.

A possible limitation to the Spearman rank procedure is that the values generated are for the entire collection and do not, say, indicate differences in a correlation values of a certain percentile. In table 2.3.3, for example, the top 20 tallest accessions (average of the two replications) from the first year in-ground are assigned a rank. The same accessions' ranks are then also given from the third-year data (also averaged from replications). The Spearman rank correlation value for final height between the two treatments was 0.68, but only eight of the original 20 tallest plants from year one were also in the top 20 in year three, or 40%. The discrepancy seen in this measurement is possibly skewed as the top 20 only represent about 13% of the entire collection (including parents and replications). Some of the top 20 in final height from first-year in-ground turned into rankings of 98^{th} and 107^{th}. The acceptable amount of outliers a selection population can contain for a new population to be of value for future breeding work remains unclear, however. If data have been collected, however, consistently through a multiyear evaluation process, it may be feasible to simply rogue out the accessions that failed to live up to their original potential and thus create a much stronger subsequent parental line.

Correlations within Third-year Data (Pearson)

The correlations of discrete traits within the third-year data can give breeders a useful insight into how these traits are associated with one another and thus whether it should be straightforward to select for any combination of traits desired. As with the comparisons between first-year and third-year data, much higher correlation values between the vegetative traits with the third-year existed. In fact, all Pearson correlation values between the third-year initial and final height and width measurements were highly correlated. This suggests it may be difficult to select for tall thin plants or short wide plants (Table 2.2.5).

Moderate negative correlations between all of the vegetative measurements and the first flower date also existed. That is to say, the greater the height or width, the earlier the first flower date would occur. This may not be a genetic correlation and instead it may be more indicative of a healthier plant being more precocious. Other data of note include an interesting correlation of 1.0 for flower duration and last flower date. Although the actual value of the correlation was rounded up for simplification, the definitions of the variables suggest that the two measurements are related. Flower duration is determined, in part, by the last flowering date and does not consider the possible large gaps in a weekly flower assessment that may take place. This point of fact is almost rendered moot, however, as there is also an extremely high correlation for last flower date with total weeks of flowering. This last item suggests that the accessions that bloom later in the season would have a high probability of having flowered consistently throughout the growing season.

The final noteworthy correlations come from the average inflorescence length and width correlations to the other floral traits. The average inflorescence length was very low or non-significant when correlated to all of the floral measurements made in the third-year. The correlations of average inflorescence width with other third-year reproductive traits were also low but the correlations did have greater significance (than did average inflorescence length). The correlation of average inflorescence width and length, however were relatively high at 0.43, suggesting that it would be only slightly difficult to produce short, wide inflorescences or long and narrow ones.

Correlations within Third-year Data (Spearman)

The Pearson (Table 2.2.5) and Spearman (Table 2.2.6) correlations of the third-year measurements were similar. All vegetative correlations were high. The total weeks of flowering also had high correlations with last flower date and total weeks of flowering. There was also a completely linear relationship (r=1.0) between last flower date and flower duration which, as discussed in the previous section, may have more to do with the definition of how flower duration is calculated. This last point is even more significant, however, when one considers that this was not the case in the first year assessment in 2007. The correlation coefficient for last flower date and flower duration in the first-year in-ground was 0.64 (the first-year container correlation between the same two traits was 0.74). The change in the correlation values between the two years' treatments may suggest that as the plants mature, they will begin flowering about the same time and so be more likely to have the same flower duration (again assuming that they will have a similar last flower date). There were relatively low correlations between vegetative and floral characteristics within the third-year data with the exception of first flower date to height and width measurements which were moderate. The Spearman correlation value for average inflorescence width to average inflorescence length came out to be just moderate with a value of 0.50.

First Year Trait Rank Comparisons to Third Year Ranks

The correlations between traits can be a useful tool for plant breeders who may want to improve traits simultaneously or select for them independently. The rank correlations illustrated in the Spearman matrices provide a different way to look at a population's traits which may also guide a breeder in the selection process. The Spearman tables detail how the ranking of traits in an ordinal fashion (high to low or low to high, either is acceptable as long as it is consistent between traits) correlate with one another. The Spearman tables generated, however, list the correlations over the entire population. These generated data would not be practical for a plant breeder who would instead only select a small portion of a population (say ten percent).

Tables 2.3.2 and 2.3.3, for example, list the top twenty accessions for greatest final height measurements in the first year container and in-ground respectively. The same accessions' ranks are then given for the third year. The average rank for the treatments is given at the bottom of each table. These rankings are also reproduced for greatest final width measurements (Tables 2.4.2 and 2.4.3), greatest flower duration (Tables 2.5.2 and 2.5.3), greatest total weeks of flowering (Tables 2.6.2 and 2.6.3), and greatest average inflorescence width (Tables 2.7.2 and 2.7.3).

Although there are occasional agreements, the average rankings for the top twenty accessions for a given trait vary widely. For the traits "flower duration" and "greatest total weeks flowering" there were a number of accessions in the third year especially that shared the same value. This fact could possibly skew the rank correlations for these traits or the average rankings in the third year.

Referencing the tables mentioned in this section, only the floral traits of "longest flower duration" and "total weeks of flowering" had lower average rank values (and so greater agreement with first-year ranks) with the first-year container treatment to third-year which again gives greater credence to selecting for traits based on in-ground evaluations.

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Table 2.1 *Vitex* accession prefixes from parental crosses and corresponding number of progeny

Accession Prefix	Parents	Number of Progeny Used
V0502	*Vitex agnus-castus* 'Shoal Creek' x *V. rotundifolia*	19
V0504A	*V. agnus-castus* 'Silver Spires' x V. agnus-castus 'Shoal Creek'	1
V0504B	*V. agnus-castus* 'Shoal Creek' x *V. agnus-castus* 'Silver Spires'	32
V0506A	*V. agnus-castus* 'Shoal Creek' x *V. agnus-castus* 'Blushing Spires'	52
V0506B	*V. agnus-castus* 'Blushing Spires' x V. agnus-castus 'Shoal Creek'	11
V0509A	*V. agnus-castus* 'Abbeville Blue' x *V. agnus-castus* 'Silver Spires'	16
V0509B	*V. agnus-castus* 'Silver Spires' x *V. agnus-castus* 'Abbeville Blue'	11

Table 2.2.1 Pearson correlation coefficients of first-year (container and in-ground) vegetative data to third-year (in-ground)

	First-year Measurements											
Third-year Measurements	Height 1		Width 1		Height 2		Width 2		Height 3		Width 3	
	C	G	C	G	C	G	C	G	C	G	C	G
Height 1	.49***	.48***	.15*	.19**	.51***	.72***	NS	.52***	.53***	.76***	.15*	.52***
Width 1	.38***	.36***	.23***	.25***	.41***	.59***	.13*	.64***	.46***	.61***	.33***	.65***
Height 2	.49***	.47***	.18**	.23***	.46***	.70***	NS	.47***	.50***	.73***	.15*	.48***
Width 2	.39***	.38***	.29***	.32***	.34***	.56***	.29***	.70***	.38***	.58***	.46***	.73***
First Flower Date	-.21**	-.17**	NS	NS	-.33***	-.29***	NS	-.40***	-.34***	-.38***	-.24***	-.42***
Last Flower Date	NS	.16**	.19**	.16**	NS	NS	NS	.21***	NS	NS	.17*	.22***
Flower Duration	NS	.19**	.19**	.18**	NS	.15*	NS	.24***	NS	.16**	.19**	.26***
Total Weeks of Flowering	NS	NS	.21**	.18**	NS	.16**	.14*	.33***	NS	.16**	.20**	.34***
Average Inflorescence Length	.27***	.20**	NS	NS	.30***	.34***	NS	.16*	.36***	.33***	.16*	.20**
Average Inflorescence Width	NS	NS	NS	NS	.29***	NS	NS	.24***	.34***	NS	.28***	.28***

C and G refer to first-year container and ground treatments, respectively. First-year Measurements Height and Width 1, 2, and 3 refer to height and width measurements taken 3 weeks, 19 weeks, and 33 weeks after planting respectively. Third-year Height and Width 1 and 2 refer to in-ground measurements taken at the beginning and end of third-year growing season (2009). NS, *, **, *** Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

Table 2.2.2 Pearson correlation coefficients of first-year (container and in-ground) reproductive data to third-year (in-ground)

Third-year Measurements	First-year Measurements													
	First Flower Date		Last Flower Date		Flower Duration		Total Weeks of Flowering		Average Inflorescence Number		Average Inflorescence Length		Average Flowers per Inflorescence	
	C	G	C	G	C	G	C	G	C	G	C	G	C	G
Height1	-.31***	-.38***	.13*	.40***	.27***	.50***	.26***	.56***	.31***	.56***	.30***	.41***	.19**	.35***
Width1	-.28***	-.31***	.14*	.43***	.24***	.46***	.27***	.55***	.29***	.61***	.18**	.28***	.19**	.37***
Height2	-.34***	-.39***	.14*	.39***	.30***	.50***	.30***	.58***	.35***	.59***	.29***	.41***	.20**	.38***
Width2	-.26***	-.32***	.14*	.40***	.25***	.44***	.28***	.53***	.34***	.59***	.20**	.33***	.16*	.36***
First Flower Date	.16*	.18**	-.17*	-.38***	-.21**	-.32***	-.18**	-.37***	NS	-.32***	NS	-.21***	NS	-.38***
Last Flower Date	.15*	NS	.15*	.22***	.19**	.21***	.18**	.23***	.24***	.25***	NS	NS	NS	.15*
Flower Duration	-.15*	-.14*	.16*	.26***	.20**	.24***	.19**	.27***	.24***	.28***	NS	NS	NS	.19**
Total Weeks of Flowering	-.14*	-.13*	.13*	.26***	.18**	.24***	.16*	.27***	.19**	.30***	-.11*	NS	NS	.18**
Average Inflorescence Length	-.31***	-.27***	NS	.24***	.31***	.33***	.27***	.35***	.14*	.17**	.54***	.60***	NS	.26***
Average Inflorescence Width	-.14*	NS	NS	NS	NS	NS	NS	.13*	NS	NS	.18*	.23***	.15*	.23***

C and G refer to first-year container and ground treatments, respectively. First-year Height and Width 1, 2, and 3 refer to height and width measurements taken 3 weeks, 19 weeks, and 33 weeks after planting. Third-year Height and Width 1 and 2 refer to in-ground measurements taken at the beginning and end of third-year growing season (2009). NS, *, **, *** Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

Table 2.2.3 Spearman correlation coefficients of first-year (container and in-ground) vegetative data to third-year (in-ground)

Third-year Measurements	First-year Measurements: Height 1 C	Height 1 G	Width 1 C	Width 1 G	Height 2 C	Height 2 G	Width 2 C	Width 2 G	Height 3 C	Height 3 G	Width 3 C	Width 3 G
Height 1	.52***	.47***	.15*	.19**	.44***	.69***	NS	.55***	.47***	.72***	.18**	.52***
Width 1	.39***	.37***	.17*	.25***	.33***	.52***	NS	.69***	.40***	.54***	.29***	.70***
Height 2	.53***	.48***	.18**	.22***	.38***	.66***	NS	.52***	.43***	.68***	.19**	.50***
Width 2	.41***	.37***	.21**	.30***	.28***	.52***	.18**	.66***	.34**	.53***	.34***	.69***
First Flower Date	-.18*	NS	NS	NS	-.28***	-.22***	NS	-.43***	-.28***	-.29***	-.27***	-.39***
Last Flower Date	NS	.18**	.19**	.17**	NS	NS	NS	.23***	NS	.12*	.14*	.24***
Flower Duration	NS	.19**	.19**	.18**	NS	.14*	NS	.26***	NS	.16*	.16*	.27***
Total Weeks of Flowering	NS	NS	.21**	.19**	NS	NS	.15*	.30***	NS	.14*	.16*	.31***
Average Inflorescence Length	.26***	.22***	NS	NS	.25***	.29***	NS	.23***	.33***	.31***	.23***	.29***
Average Inflorescence Width	NS	NS	NS	NS	.19**	NS	NS	.19**	.24***	NS	.14*	.19**

C and G refer to first-year container and ground treatments, respectively. First-year Height and Width 1, 2, and 3 refer to height and width measurements taken 3 weeks, 19 weeks, and 33 weeks after planting respectively. Third-year Height and Width 1 and 2 refer to in-ground measurements taken at the beginning and end of third-year growing season (2009). NS, *, **, *** Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

Table 2.2.4 Spearman correlation coefficients of first-year (container and in-ground) reproductive data to third-year (in-ground)

Third-year Measurements	First Flower Date C	First Flower Date G	Last Flower Date C	Last Flower Date G	Flower Duration C	Flower Duration G	Total Weeks of Flowering C	Total Weeks of Flowering G	Average Inflorescence Number C	Average Inflorescence Number G	Average Inflorescence Length C	Average Inflorescence Length G	Average Flowers per Inflorescence C	Average Flowers per Inflorescence G
Height 1	-.36***	-.37***	NS	.36***	.19**	.46***	.22***	.54***	.33***	.55***	.30***	.39***	.17*	.30***
Width 1	-.33***	-.29***	NS	.33***	.16*	.40***	.21**	.51***	.28***	.59***	.19**	.27***	.17*	.31***
Height 2	-.41***	-.40***	NS	.38***	.23***	.50***	.26***	.57***	.38***	.58***	.30***	.38***	.20**	.33***
Width 2	-.37***	-.34***	NS	.34***	.18**	.43***	.25***	.51***	.37***	.60***	.22**	.33***	.16*	.30***
First Flower Date	.24***	.15*	NS	-.18**	-.14*	-.22***	-.16*	-.25***	NS	-.26***	-.15*	-.22***	-.19**	-.35***
Last Flower Date	-.17*	-.16**	NS	.22***	.20**	.24***	.19**	.28***	.22**	.26***	NS	NS	NS	.14*
Flower Duration	-.17**	-.17**	NS	.24***	.21**	.25***	.20**	.30***	.21**	.28***	NS	NS	NS	.18**
Total Weeks of Flowering	-.16*	-.12*	NS	.23***	.18**	.20***	.17**	.26***	.17*	.26***	NS	NS	NS	.15***
Average Inflorescence Length	-.28***	-.23***	.15*	.21***	.28***	.28***	.27***	.29***	.15*	.17**	.55***	.56***	NS	.20**
Average Inflorescence Width	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	.31***	.32***	.23***	.31***

C and G refer to first-year container and ground treatments, respectively. First-year Height and Width 1, 2, and 3 refer to height and width measurements taken 3 weeks, 19 weeks, and 33 weeks after planting respectively. Third-year Height and Width 1 and 2 refer to in-ground measurements taken at the beginning and end of third-year growing season (2009). NS, *, **, *** Nonsignificant or significant at *P*≤0.05, 0.01, or 0.001, respectively.

Table 2.2.5 Pearson correlation coefficients of third-year (in-ground) measurements

Third-year Measurements	Height 1	Width 1	Height 2	Width 2	First Flower Date	Last Flower Date	Flower Duration	Total Weeks of Flowering	Average Inflorescence Length	Average Inflorescence Width
Height 1		.86***	.94***	.79***	-.59***	.22***	.27***	.28***	.35***	.16*
Width 1	.86***		.85***	.89***	-.67***	.35***	.40***	.45***	.33***	.30***
Height 2	.94***	.85***		.82***	-.59***	.26***	.31***	.33***	.41***	.22***
Width 2	.79***	.89***	.82***		-.64***	.33***	.38***	.42***	.40***	.32***
First Flower Date	-.59***	-.67***	-.59***	-.64***		-.25***	-.33***	-.33***	-.28***	-.35***
Last Flower Date	.22***	.35***	.26***	.33***	-.25***		1.0***	.83***	NS	.17**
Flower Duration	.27***	.40***	.31***	.38***	-.33***	1.0***		.84***	NS	.19**
Total Weeks of Flowering	.28***	.45***	.33***	.42***	-.33***	.83***	.84***		NS	.17**
Average Inflorescence Length	.35***	.33***	.41***	.40***	-.28***	NS	NS	NS		.43***
Average Inflorescence Width	.16*	.30***	.22***	.32***	-.35***	.17**	.19**	.17**	.43***	

Height and Width 1 and 2 refer to in-ground measurements taken at the beginning and end of third-year growing season (2009). NS, *, **, *** Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

Table 2.2.6 Spearman correlation coefficients of third-year (in-ground) measurements

Third-year Measurements	Height 1	Width 1	Height 2	Width 2	First Flower Date	Last Flower Date	Flower Duration	Total Weeks of Flowering	Average Inflorescence Length	Average Inflorescence Width
Height 1		.81***	.94***	.78***	-.46***	.22***	.25***	.21***	.32***	.13*
Width 1	.81***		.81***	.86***	-.56***	.36***	.40***	.40***	.30***	.21***
Height 2	.94***	.81***		.81***	-.45***	.28***	.30***	.27***	.38***	.18**
Width 2	.78***	.86***	.81***		-.50***	.33***	.37***	.35***	.38***	.20**
First Flower Date	-.46***	-.56***	-.45***	-.50***		-.21***	-.28***	-.25***	-.28***	-.43***
Last Flower Date	.22***	.36***	.28***	.33***	-.21***		1.0***	.85***	NS	NS
Flower Duration	.25***	.40***	.30***	.37***	-.28***	1.0***		.86***	NS	NS
Total Weeks of Flowering	.21***	.40***	.27***	.35***	-.25***	.85***	.86***		NS	NS
Average Inflorescence Length	.32***	.30***	.38***	.38***	-.28***	NS	NS	NS		.50***
Average Inflorescence Width	.13*	.21***	.18**	.20**	-.43***	NS	NS	NS	.50***	

Height and Width 1 and 2 refer to in-ground measurements taken at the beginning and end of third-year growing season (2009).
NS, *, **, *** Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

Table 2.3.1 Accessions with tallest final height in each of the three treatments

Tallest of Final Height Measurements								
Ground 1st year			Container 1st year			Ground 3rd Year		
Rank	Accession	cm	Rank	Accession	cm	Rank	Accession	Cm
1	V0506B-11	174.0	1	V0506A-59	179.0	1	V0506B-11	280.0
2	V0509A-16	167.0	2	V0502-7	166.5	2	V0502-7	270.0
3	V0506A-69	164.0	3	V0506A-5	153.0	3	V0506B-7	267.5
4	V0506A-43	161.0	4	V0504B-47	147.0	4	V0506A-14	266.5
5	V0506A-78	160.0	5	V0506A-19	145.0	4	V0506A-27	266.5
6	V0502-17	159.0	6	V0502-17	144.0	6	V0509A-16	266.0
7	V0506A-5	156.5	7	V0504B-44	136.0	7	V0504B-16	258.0
8	V0506A-52	153.5	8	V0509A-22	132.5	8	V0506A-78	255.5
9	V0506A-19	152.5	9	V0506A-80	132.0	9	V0506A-29	251.0
10	V0506A-9	152.0	10	V0504B-28	131.0	10	V0506A-61	250.5
11	V0502-14	151.5	11	V0502-14	130.0	11	V0504A-2	248.5
12	V0506B-7	150.5	12	V0504B-38	128.5	12	V0504B-44	246.5
13	V0506A-59	150.0	12	V0506A-29	128.5	13	V0506A-43	245.5
14	V0509A-10	148.0	14	V0502-2	127.5	14	V0506A-36	245.0
15	V0506A-20	145.5	15	V0506A-37	127.0	14	V0506A-49	245.0
16	V0506A-75	143.5	16	V0506A-71	126.5	16	V0504B-46	243.5
17	V0506B-9	143.0	17	V0509A-14	126.0	17	V0504B-42	243.5
18	V0509B-17	142.5	18	V0504B-22	125.0	17	V0506A-63	243.5
19	V0506A-36	142.0	18	V0504B-36	125.0	19	V0502-17	242.5
20	V0506A-80	141.5	20	V0509A-15	123.0	19	V0506B-9	242.5

Table 2.3.2 Comparisons of 3rd year in-ground rank of the tallest container grown plants from 1st year

Accession	Rank 1st year container	cm	Rank 3rd year in-ground	cm
V0506A-59	1	179	26	236.5
V0502-7	2	166.5	2	270.0
V0506A-5	3	153	39	227.0
V0504B-47	4	147	112	144.0
V0506A-19	5	145	39	227.0
V0502-17	6	144	19	242.5
V0504B-44	7	136	12	246.5
V0509A-22	8	132.5	67	197.0
V0506A-80	9	132	76	190.5
V0504B-28	10	131	132	98.00
V0502-14	11	130	98	169.5
V0504B-38	12	128.5	82	183.0
V0506A-29	12	128.5	9	251.0
V0502-2	14	127.5	56	207.5
V0506A-37	15	127	104	161.0
V0506A-71	16	126.5	91	175.0
V0509A-14	17	126	65	199.0
V0504B-22	18	125	29	234.0
V0504B-36	18	125	44	221.5
V0509A-15	20	123	69	195.5
Average Rank	10.4	-	58.55	

Table 2.3.3 Comparisons of 3rd year in-ground rank of the tallest in-ground grown plants from 1st year

Accession	Rank 1st year in-ground	cm	Rank 3rd year in-ground	cm
V0506B-11	1	174	1	280.0
V0509A-16	2	167	6	266.0
V0506A-69	3	164	31	232.0
V0506A-43	4	161	13	245.5
V0506A-78	5	160	8	255.5
V0502-17	6	159	19	242.5
V0506A-5	7	156.5	39	227.0
V0506A-52	8	153.5	31	232.0
V0506A-19	9	152.5	39	227.0
V0506A-9	10	152	37	228.0
V0502-14	11	151.5	98	169.5
V0506B-7	12	150.5	3	267.5
V0506A-59	13	150	26	236.5
V0509A-10	14	148	66	198.0
V0506A-20	15	145.5	30	233.0
V0506A-75	16	143.5	107	159.0
V0506B-9	17	143	19	242.5
V0509B-17	18	142.5	87	177.5
V0506A-36	19	142	14	245.0
V0506A-80	20	141.5	76	190.5
Average Rank	10.5	-	37.5	-

Table 2.4.1 Accessions with widest final width in each treatment.

Widest of final width measurements								
Ground 1st Year			Container 1st Year			Ground 3rd Year		
Rank	**Accession**	**cm**	**Rank**	**Accession**	**cm**	**Rank**	**Accession**	**Cm**
1	V. rotundifolia	348.9	1	V. rotundifolia	172.4	1	V. rotundifolia	438.4
2	V0502-7	224.0	2	V0502-7	137.0	2	V0502-7	432.5
3	V0506A-69	193.0	3	V0506A-65	112.0	3	V0506A-43	381.5
4	V0506B-9	183.0	4	V0509A-5	111.0	4	V0504B-44	373.5
5	V0506A-37	182.0	5	V0506A-72	109.0	5	V0506A-65	359.0
6	V0504B-44	173.0	6	V0504B-32	102.5	6	V0506B-11	355.5
7	V0509A-16	169.5	7	V0506A-37	100.0	7	V0504B-42	340.5
8	V0506A-48	169.0	8	V0504B-38	98.50	8	V0509A-16	340.0
9	V0509A-5	168.5	9	V0502-13	98.00	9	V0506A-78	331.0
10	V0506A-5	164.5	10	V0509A-7	96.00	9	V0506A-73	331.0
11	V0504B-4	161.5	11	V0506A-7	92.00	11	V0506A-5	326.5
12	V0506A-56	161.0	12	V0506A-56	90.50	12	V0506A-36	326.0
13	V0506A-65	160.5	13	V0506A-73	89.00	12	V0506A-1	326.0
14	V0509A-8	159.5	13	V0504B-4	89.00	14	V0506A-56	325.5
15	V0506A-49	156.5	15	V0506A-20	88.00	15	V0506A-29	324.0
16	V0506A-20	156.0	15	V0504B-19	88.00	16	V0504B-16	322.5
17	V0502-2	154.5	15	V0506A-71	88.00	17	V0506A-14	317.5
17	V0504B-11	154.5	18	V0509B-17	87.00	18	V0504B-46	316.5
19	V0506A-78	153.5	18	V0506A-58	87.00	19	Blushing Spires	316.4
20	V0504B-19	153.0	18	V0504B-37	87.00	20	V0506B-15	311.5

Table 2.4.2 Comparisons of 3rd year in-ground rank of the widest container grown plants from 1st year

Accession	Rank 1st year container	cm	Rank 3rd year in-ground	cm
V. rotundifolia	1	172.4	1	438.4
V0502-7	2	137.0	2	432.5
V0506A-65	3	112.0	5	359.0
V0509A-5	4	111.0	36	293.5
V0506A-72	5	109.0	125	142.0
V0504B-32	6	102.5	104	207.5
V0506A-37	7	100.0	87	241.0
V0504B-38	8	98.50	96	232.5
V0502-13	9	98.00	112	196.5
V0509A-7	10	96.00	57	268.5
V0506A-7	11	92.00	41	288.0
V0506A-56	12	90.50	14	325.5
V0506A-73	13	89.00	9	331.0
V0504B-4	13	89.00	56	271.0
V0506A-20	15	88.00	46	284.0
V0504B-19	15	88.00	32	298.5
V0506A-71	15	88.00	55	272.0
V0509B-17	18	87.00	89	237.5
V0506A-58	18	87.00	109	200.0
V0504B-37	18	87.00	78	248.0
Average Rank	10.15	-	57.7	-

Table 2.4.3 Comparisons of 3rd year in-ground rank of the widest in-ground grown plants from 1st year

Accession	Rank 1st year in-ground	cm	Rank 3rd year in-ground	cm
V. rotundifolia	1	348.9	1	438.4
V0502-7	2	224	2	432.5
V0506A-69	3	193	58	268.0
V0506B-9	4	183	43	287.5
V0506A-37	5	182	87	241.0
V0504B-44	6	173	4	373.5
V0509A-16	7	169.5	8	340.0
V0506A-48	8	169	38	289.5
V0509A-5	9	168.5	36	293.5
V0506A-5	10	164.5	11	326.5
V0504B-4	11	161.5	56	271.0
V0506A-56	12	161	14	325.5
V0506A-65	13	160.5	5	359.0
V0509A-8	14	159.5	67	258.5
V0506A-49	15	156.5	44	286.0
V0506A-20	16	156	46	284.0
V0502-2	17	154.5	39	289.0
V0504B-11	17	154.5	65	263.5
V0506A-78	19	153.5	9	331.0
V0504B-19	20	153	32	298.5
Average Rank	10.45	-	33.25	-

Table 2.5.1 Greatest flower duration in each treatment

Flower Duration								
Ground 1st Year			**Container 1st year**			**Ground 3rd Year**		
Rank	**Accession**	**Weeks**	**Rank**	**Accession**	**Weeks**	**Rank**	**Accession**	**Weeks**
1	V0506B-2	24.0	1	V0506B-16	25.0	1	V0504A-2	24.0
2	V0506A-69	22.5	2	V0506B-1	23.0	1	V0506A-42	24.0
3	V0506A-73	22.0	3	V0506B-6	22.0	1	V0502-33	24.0
3	V0506A-76	22.0	4	V0506A-65	20.5	1	V0506A-5	24.0
3	V0506B-7	22.0	4	V0506A-69	20.5	1	V0506A-65	24.0
3	V0509A-7	22.0	4	V0504B-21	20.5	1	V0506A-36	24.0
3	V0509A-3	22.0	7	V0506B-14	20.0	1	V0504B-16	24.0
3	V0506B-1	22.0	7	V0504B-38	20.0	1	V0509B-19	24.0
9	V0504A-2	21.0	7	V0509B-21	20.0	9	V0506A-7	23.5
9	V0506B-9	21.0	10	Silver Spires	19.6	9	V0506A-14	23.5
9	V0506A-42	21.0	11	V0506A-73	19.5	9	V0504B-46	23.5
12	Blushing Spires	20.8	11	V0506B-9	19.5	9	V0504B-21	23.5
13	V0506A-7	20.5	11	V0502-33	19.5	9	V0504B-22	23.5
13	V0502-33	20.5	14	Blushing Spires	19.4	9	V0504B-38	23.5
15	V0509A-16	20.0	15	V0509A-8	19.0	9	V0509A-22	23.5
15	V0506A-78	20.0	15	V0509B-18	19.0	9	V0506A-43	23.5
15	V0506A-14	20.0	15	V0502-13	19.0	9	V0502-7	23.5
15	V0506B-15	20.0	18	V0506A-76	18.5	9	V0504B-1	23.5
15	V0506A-19	20.0	18	V0509A-3	18.5	19	V0506A-3	23.0
15	V0506A-23	20.0	20	V0504B-22	18.0	19	V0509A-25	23.0

Table 2.5.2 Comparisons of 3rd year in-ground rank of the greatest flowering duration container grown plants from 1st year

Accession	Rank 1st year container	Weeks	Rank 3rd year in-ground	Weeks
V0506B-16	1	25.0	81	13.5
V0506B-1	2	23.0	84	13.0
V0506B-6	3	22.0	100	11.0
V0506A-65	4	20.5	1	24.0
V0506A-69	4	20.5	65	15.0
V0504B-21	4	20.5	9	23.5
V0506B-14	7	20.0	36	20.5
V0504B-38	7	20.0	9	23.5
V0509B-21	7	20.0	137	3.00
Silver Spires	10	19.6	45	19.1
V0506A-73	11	19.5	25	22.0
V0506B-9	11	19.5	73	14.0
V0502-33	11	19.5	1	24.0
Blushing Spires	14	19.4	58	17.1
V0509A-8	15	19.0	63	15.5
V0509B-18	15	19.0	25	22.0
V0502-13	15	19.0	41	20.0
V0506A-76	18	18.5	121	8.00
V0509A-3	18	18.5	29	21.5
V0504B-22	20	18.0	9	23.5
Average Rank	9.85	-	50.6	-

Table 2.5.3 Comparisons of 3rd year in-ground rank of the longest flowering duration in-ground grown plants from 1st year

Accession	Rank 1st year in-ground	Weeks	Rank 3rd year in-ground	Weeks
V0506B-2	1	24.0	90	12.0
V0506A-69	2	22.5	65	15.0
V0506A-73	3	22.0	25	22.0
V0506A-76	3	22.0	121	8.0
V0506B-7	3	22.0	29	21.5
V0509A-7	3	22.0	81	13.5
V0509A-3	3	22.0	29	21.5
V0506B-1	3	22.0	84	13.0
V0504A-2	9	21.0	1	24.0
V0506B-9	9	21.0	73	14.0
V0506A-42	9	21.0	1	24.0
Blushing Spires	12	20.8	58	17.1
V0506A-7	13	20.5	9	23.5
V0502-33	13	20.5	1	24.0
V0509A-16	15	20.0	136	4.50
V0506A-78	15	20.0	46	19.0
V0506A-14	15	20.0	9	23.5
V0506B-15	15	20.0	65	15.0
V0506A-19	15	20.0	99	11.0
V0506A-23	15	20.0	104	10.5
Average Rank	8.8	-	56.3	-

Table 2.6.1 Greatest total weeks flowering ranks in each treatment

Total Weeks Flowering								
Ground 1st year			**Container 1st year**			**Ground 3rd year**		
Rank	**Accession**	**Weeks**	**Rank**	**Accession**	**Weeks**	**Rank**	**Accession**	**Weeks**
1	V0506A-69	22.5	1	V0506B-16	23.0	1	V0506A-36	24.0
2	V0506A-73	22.0	2	V0506B-6	21.0	2	V0506A-42	23.5
2	V0509A-3	22.0	3	V0504B-38	20.0	2	V0502-7	23.5
4	V0506A-27	21.5	3	V0506B-14	20.0	4	V0506A-17	23.0
5	V0504A-2	21.0	3	V0506B-1	20.0	5	V0504B-19	22.5
5	V0506A-42	21.0	6	V0502-33	19.5	5	V0502-31	22.5
5	V0506A-7	21.0	7	V0506A-76	18.5	7	V0504B-46	22.0
5	V0506B-7	21.0	8	V0506A-73	18.0	7	V0506A-58	22.0
5	Blushing Spires	21.0	8	V0509B-14	18.0	9	V0506B-7	21.5
5	V0506B-9	21.0	8	Blushing Spires	18.0	10	V0506A-5	21.0
11	V0506A-78	20.5	8	V0506B-9	18.0	10	V0504B-32	21.0
12	V0506A-14	20.0	12	V0506A-65	17.5	12	V0506A-14	20.5
12	V0506B-12	20.0	12	V0506A-42	17.5	12	V0509A-18	20.5
12	V0506B-15	20.0	12	V0504B-41	17.5	14	V0502-33	20.0
12	V0509A-7	20.0	12	V0506A-79	17.5	14	V0509A-22	20.0
12	V0506A-76	20.0	12	V0506A-56	17.5	14	V0506A-43	20.0
12	V0509A-16	20.0	17	Silver Spires	17.1	17	V0504A-2	19.5
18	V0502-33	19.5	18	V0504B-21	17.0	17	V0506A-61	19.5
18	V0504B-46	19.5	18	V0504B-19	17.0	17	V0506A-3	19.5
18	V0506A-49	19.5	18	V0506A-58	17.0	20	V0506B-14	19.0

Table 2.6.2 Comparisons of 3rd year in-ground rank of the greatest total weeks flowering container grown plants from 1st year

Accession	Rank 1st year container	Weeks	Rank 3rd year in-ground	Weeks
V0506B-16	1	23	51	13.0
V0506B-6	2	21	69	11.0
V0504B-38	3	20	43	14.0
V0506B-14	3	20	20	19.0
V0506B-1	3	20	85	9.50
V0502-33	6	19.5	14	20.0
V0506A-76	7	18.5	117	6.00
V0506A-73	8	18	69	11.0
V0509B-14	8	18	52	12.5
Blushing Spires	8	18	68	11.1
V0506B-9	8	18	58	12.0
V0506A-65	12	17.5	23	18.5
V0506A-42	12	17.5	2	23.5
V0504B-41	12	17.5	52	12.5
V0506A-79	12	17.5	36	15.5
V0506A-56	12	17.5	43	14.0
Silver Spires	17	17.1	57	12.3
V0504B-21	18	17	26	17.0
V0504B-19	18	17	5	22.5
V0506A-58	18	17	7	22.0
Average Rank	9.4	-	44.85	-

Table 2.6.3 Comparisons of 3rd year in-ground rank of the greatest total weeks flowering in-ground grown plants from 1st year

Accession	Rank 1st year in-ground	Weeks	Rank 3rd year in-ground	Weeks
V0506A-69	1	22.5	69	11.0
V0506A-73	2	22.0	69	11.0
V0509A-3	2	22.0	26	17.0
V0506A-27	4	21.5	127	5.0
V0504A-2	5	21.0	17	19.5
V0506A-42	5	21.0	2	23.5
V0506A-7	5	21.0	32	16.5
V0506B-7	5	21.0	9	21.5
Blushing Spires	5	21.0	68	11.1
V0506B-9	5	21.0	58	12.0
V0506A-78	11	20.5	38	15.0
V0506A-14	12	20.0	12	20.5
V0506B-12	12	20.0	25	18.0
V0506B-15	12	20.0	85	9.50
V0509A-7	12	20.0	104	7.50
V0506A-76	12	20.0	116	6.00
V0509A-16	12	20.0	132	4.50
V0502-33	18	19.5	14	20.0
V0504B-46	18	19.5	7	22.0
V0506A-49	18	19.5	26	17.0
Average Rank	8.8	-	51.8	-

Table 2.7.1 Longest average inflorescence rankings in each treatment

Longest Average Inflorescence								
Ground 1st year			**Container 1st year**			**Ground 3rd year**		
Rank	**Accessions**	**cm**	**Rank**	**Accessions**	**cm**	**Rank**	**Accessions**	**cm**
1	V0506A-59	43.31	1	V0506A-59	38.83	1	V0506A-59	47.58
2	V0506A-52	28.08	2	V0506A-80	30.83	2	V0504B-22	42.17
3	V0509A-19	26.29	3	V0506A-19	28.50	3	V0504B-41	40.58
4	V0506A-11	26.00	4	V0506A-11	24.50	4	V0506A-56	37.84
5	V0506A-43	25.34	5	V0509A-8	24.41	5	V0506A-65	36.08
6	V0504B-41	25.32	6	V0509A-3	23.75	6	V0506A-20	35.25
7	V0504B-22	25.04	7	V0504B-22	22.92	7	V0504B-12	35.00
8	V0506A-65	25.00	8	V0509A-19	22.86	7	Abbeville Blue	35.00
8	V0506A-75	25.00	9	V0506A-76	22.79	9	V0506A-19	34.92
10	V0506A-5	24.44	10	V0506A-43	22.53	9	V0506A-71	34.92
11	V0506A-26	24.40	11	V0506A-73	22.41	11	V0509A-7	34.84
12	V0509A-16	24.37	12	V0506A-29	22.33	12	V0509B-5	34.83
13	V0506A-73	24.32	13	V0509A-22	21.69	13	V0504B-4	34.33
14	V0504B-9	24.11	14	V0502-17	21.68	14	Shoal Creek	34.04
15	V0509A-25	23.57	15	V0506A-5	21.50	15	V0509B-13	34.00
16	V0509A-5	23.50	16	V0509A-5	21.40	16	V0506A-23	33.75
17	V0506A-80	23.07	17	V0504B-39	21.31	17	V0506A-32	33.42
18	V0506A-56	22.84	18	V0509A-25	20.18	18	V0506B-11	33.17
19	V0504B-44	22.70	19	V0504B-12	20.02	19	Silver Spires	33.15
20	V0509A-11	22.67	20	V0506A-78	19.95	20	V0506B-9	33.09

Table 2.7.2 Comparisons of 3rd year in-ground rank of the greatest average inflorescence length to in-ground grown plants from 1st year

Accession	Rank 1st year container	cm	Rank 3rd year in-ground	cm
V0506A-59	1	38.83	1	47.58
V0506A-80	2	30.83	59	27.42
V0506A-19	3	28.50	9	34.92
V0506A-11	4	24.50	23	32.84
V0509A-8	5	24.41	115	17.17
V0509A-3	6	23.75	41	29.84
V0504B-22	7	22.92	2	42.17
V0509A-19	8	22.86	32	31.34
V0506A-76	9	22.79	55	27.73
V0506A-43	10	22.53	27	32.25
V0506A-73	11	22.41	45	29.67
V0506A-29	12	22.33	32	31.34
V0509A-22	13	21.69	67	25.67
V0502-17	14	21.68	21	32.92
V0506A-5	15	21.50	29	31.75
V0509A-5	16	21.40	21	32.92
V0504B-39	17	21.31	-	-
V0509A-25	18	20.18	62	27.00
V0504B-12	19	20.02	7	35.00
V0506A-78	20	19.95	67	25.67
Average Rank	10.5	-	37.63	-

Table 2.7.3 Comparisons of select accession average inflorescence length ranks from first-year in-ground to third-year in-ground.

Accession	Rank 1st year in-ground	cm	Rank 3rd year in-ground	cm
V0506A-59	1	43.31	1	47.58
V0506A-52	2	28.08	52	28.09
V0509A-19	3	26.29	32	31.34
V0506A-11	4	26.00	23	32.84
V0506A-43	5	25.34	27	32.25
V0504B-41	6	25.32	3	40.58
V0504B-22	7	25.04	2	42.17
V0506A-65	8	25.00	5	36.08
V0506A-75	8	25.00	118	16.42
V0506A-5	10	24.44	29	31.75
V0506A-26	11	24.40	48	29.09
V0509A-16	12	24.37	54	27.84
V0506A-73	13	24.32	45	29.67
V0504B-9	14	24.11	56	27.67
V0509A-25	15	23.57	62	27.00
V0509A-5	16	23.50	21	32.92
V0506A-80	17	23.07	59	27.42
V0506A-56	18	22.84	4	37.84
V0504B-44	19	22.70	36	30.83
V0509A-11	20	22.67	36	30.83
Average Rank	10.45	-	35.65	-

CHAPTER 3

PROPAGATION OF *PIERIS* SP. ERICACEAE (L.)

McNeill, R. D. and D. A. Knauft. To be submitted to the *International Plant Propagator's Society*

Abstract

A collection of several species and cultivars within the genus *Pieris* L. was obtained over a period of time from 2006-2008 to use in a experiment whereby individual accessions were vegetatively propagated through terminal cuttings in late summer of 2007. The initial propagation methods were very successful with rooting percentages over 90% for many of the 50+ taxa that were included.

The successful rooting of *Pieris* in late summer coincides with propagation studies and literature on the subject. Experiments that require newly rooted cuttings of *Pieris* at different times of the year may be difficult to conduct. A second propagation study to test whether or not vegetative cuttings of *Pieris* could be made in other times of the year was performed. Four *Pieris* taxa with numerous, extant container populations were vegetatively propagated every other month in the calendar year 2009. The success of the cuttings (>50.0% rooting) demonstrated that year round propagation of *Pieris* can be made.

Introduction and Literature Review

Pieris is a genus of evergreen, flowering shrubs within the plant family Ericaceae. Ericaceae also contains many common genera of ornamental shrubs including *Rhododendron* (Azaleas and Rhododendrons), *Kalmia* (Mountain Laurel), and *Arbutus* (Strawberry Shrub) (Dirr, 1998). There are numerous varieties and sub-species in *Pieris*, some of which are often listed as discrete species. Synonyms for the genus *Pieris* also exist, such as *Lyonia*, *Andromeda*, and *Arcterica.* Current taxonomic classification used by the USDA's Germplasm Resources Information Network lists only five species in *Pieris*:

Pieris floribunda (Pursh) Benth. & Hook. f.

Pieris formosa (Wall.) D. Don

Pieris japonica (Thunb.) D. Don ex G. Don

Pieris nana (Maxim.) Makino

Pieris phillyreifolia (Hook.) DC.

These species have native ranges in the Eastern United States (including two species with native ranges in Georgia) and Southeastern Asia. There are dozens of cultivars of *Pieris* commercially available with most of those being from *P. japonica* and its hybrids. The stability or consistency of a named cultivar in ornamental plants is achieved primarily through vegetative propagation, although some plants (primarily annuals) can demonstrate uniformity via seed propagation. The ability to clone a plant ensures that desirable traits are fixed from one generation to the next and so eliminate the variation that can occur through segregation and recombination of gametes in sexual reproduction.

Many plants that are vegetatively propagated have a specific time frame in which successful propagation is more likely. Dirr and Heuser (2006) report that softwood and greenwood terminal cuttings from *P. japonica* and its cultivars root readily when taken in July and August. They also report excellent rooting percentages from cuttings taken in October and November when bottom heat and fungicides are provided. This same extended period or window for *P. japonica*'s successful vegetative propagation is also reported by Lane (1988) who states that June through July and September through December are optimal times of year for cuttings. The late fall propagation of *P. phillyreifolia* (Mid-November) is also discussed by Dirr and Heuser and they report good results of cuttings taken at this time (2006).

Artlett and Artlett (1985) detail the successful rooting of *Pieris* using Growool propagation sheets as well as rooting hormone and mist. Their propagation of *Pieris* in February, March and even into early April coincides with late summer and early fall for their nursery located in New South Wales, Australia. English nurseryman Catt (1975) also has success with fall (autumn) propagation of *Pieris* and reports successful rooting of imported stock from New Zealand with mist but no rooting hormone. An extensive assortment of *Pieris* by another English nurseryman, Pearce (2000) is also primarily propagated from June to October. Pearce does state that successful rooting of cuttings after October can occur but with lower percentages and greater variability in rooting response. Nelson (1983) offers a stricter timing for the cuttings he takes at his nursery in North Carolina, namely between July and August. Another American nurseryman, Edward Losely reports that he takes cuttings of the Ericaceous plants *Leucothoe* and *Pieris* in mid-October (1980). *Pieris floribunda* can have excellent quality of roots as well as rooting percentages greater than 50% when propagated in March and July with hormone and bottom heat. The cultivar *P.f.* 'Millstream' is also reported as having excellent root quality and high rooting percentages from cuttings taken in November and December (Fordham, 1977).

There is a consistency or agreement that *Pieris* species and cultivars are most successful taken in midsummer through the fall, but there is little written about late winter and spring propagation. This is most likely due to the lack of newly hardened growth or softwood that is most conducive to adventitious root formation. Spring flowering of *Pieris* may also divert crucial resources that are necessary for root formation on cuttings. Evaluations of *Pieris* for their ability to root at different times throughout the year were conducted in 2009. This study followed another large scale germplasm propagation series with a collection of 50+ taxa in the summer and fall of 2007. The ability to successfully propagate *Pieris* throughout the year is of great importance to plant scientists who may need a constant source of newly rooted cuttings on which to perform experiments on root development, vegetative growth or disease inoculation and screening.

Materials and Methods

Approximately 50 varieties of *Pieris japonica* as well as other *Pieris* species and hybrids were vegetatively propagated through stem cuttings in July and September 2007. Stems were cut from the stock plants with 4 to 5 nodes below the apical meristem. The bottom leaves were removed from the stem and 5 to six stems were gathered together by hand with the apices held at the same point. The top leaves remaining on these cuttings were drawn up together and then cut with pruners. This shearing of leaves was done to reduce the transpiration of water while the cuttings were developing roots as well as to keep the leaves of the cuttings from touching one another while in their respective pots during the rooting period.

The cuttings were then treated with a five second basal dip of liquid KIBA at a rate of 3,000 parts per million (ppm). The individual cuttings were then inserted into 4 inch pots that contained a medium consisting of a ratio of 3:1 peat to perlite. The four inch pots were held in 16 cell trays and cuttings were placed on a mist bench for approximately 6 weeks. The misting system produced a fine mist pulse for five seconds every 15 minutes during the daylight hours, which during this period ranged from 7 a.m. to 6 p.m. Cuttings were evaluated periodically to assess the health and production of root initials and roots until they were removed from the mist bench (approximately eight weeks). The cuttings were then assayed for the production of roots and their respective rooting percentages were recorded (Tables 3.1.1 and 3.1.2).

A second propagation experiment consisted of four cultivars with significant stock quantities ('Temple Bells', *P. phillyreifolia*, 'Scarlet O'Hara', and 'Snow Drift') that were propagated during the "off season". 18 cuttings were taken of each of the four cultivars every other month beginning in February of 2009. Cuttings were limited to 18 during each round to ensure that the stock plants were not depleted of vegetative growth. The cuttings were made and prepared using the same protocols and mentioned previously. The 18 cuttings of each of the four varieties were assayed and evaluated for root development prior to the subsequent round of cuttings' placement in the mist bench. The rooting percentages for each round of cuttings were recorded for the six months in calendar year 2009 (Table 3.2).

Results and Discussion

The 2007 propagation experiment demonstrated diversity in rooting percentages across the many *P. japonica* cultivars as well as hybrids with *P. floribunda* and *P. formosa*. Ranges within the two groups (Table 3.1.1 and Table 3.1.2) ranged from 100% to zero. Due to the number of stock plants initially available and their diversity in size/habit, there were some varieties that had much lower numbers of cuttings prepared. This may have skewed the rooting percentages for small groupings.

The second propagation experiment demonstrated that there is credence to the propagation of various *Pieris* cultivars throughout the year. There was also variation seen between these four accessions and their successful production of roots at different times of the year. The absence of reports or data to suggest that *Pieris* can be vegetatively propagated in the late winter and into spring does not preclude its actual performance. The flower production and development of *Pieris* takes place during the Winter and Spring and so many propagators would not want to deal with apical or terminal cuttings that had inflorescences already developing (or developed). Flower production and development can be a considerable strain on a cutting's resources that need to be channeled into the development of adventitious roots.

The ability to propagate *Pieris* or other woody ornamentals year-round is important to many researchers. Pathologists who would like to inoculate and evaluate cuttings (especially rooted cuttings for use in root rot assays) can do so multiple times throughout the year and not be retrained to a small window in which cuttings can be produced. Horticulturists can also benefit from the knowledge that cuttings can be produced at different times of the year to meet specific requests from customers and clients.

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Table 3.1.1 Rooting percentages of select *Pieris* taxa 19 July, 2007

Pieris accessions	Date of cuttings	Peat to perlite ratio	Rooting hormone (KIBA) rate	# cuttings made	Date removed from mist	# cuttings rooted	Rooting %
Pieris floribunda × *P. japonica* 'Brouwer's Beauty' (Briggs)	07-19-07	3:1	0.3K	19	09-25-07	19	100
Pieris japonica 'Cavatine' (Briggs)	07-19-07	3:1	0.3K	11	09-25-07	7	63.6
Pieris japonica 'Cavatine' (Cofer's)	07-19-07	3:1	0.3K	10	09-25-07	9	90.0
Pieris japonica 'Compacta' (Briggs)	07-19-07	3:1	0.3K	10	09-25-07	5	50.0
Pieris japonica 'Dodd's Crystal Cascade Falls' (Cofer's)	07-19-07	3:1	0.3K	14	09-25-07	8	57.1
Pieris japonica 'Dodd's Pearl Falls' (Cofer's)	07-19-07	3:1	0.3K	10	09-25-07	8	80.0
Pieris japonica 'Dodd's Sugar Run Falls' (Cofer's)	07-19-07	3:1	0.3K	10	09-25-07	6	60.0
Pieris japonica 'Dorothy Wycoff' (Forest Farm)	07-19-07	3:1	0.3K	28	09-25-07	12	42.9
Pieris japonica 'Flaming Silver' (Briggs)	07-19-07	3:1	0.3K	23	09-25-07	18	78.3
Pieris japonica 'Flaming Silver' (Forest Farm)	07-19-07	3:1	0.3K	17	09-25-07	13	76.5
Pieris japonica 'Karenoma' (Briggs)	07-19-07	3:1	0.3K	10	09-25-07	8	80.0
Pieris japonica 'Little Heath' (Briggs)	07-19-07	3:1	0.3K	10	09-25-07	9	90.0
Pieris japonica 'Little Heath' (Forest Farm)	07-19-07	3:1	0.3K	13	09-25-07	6	46.2
Pieris japonica 'Mountain Fire' (Briggs)	07-19-07	3:1	0.3K	15	09-25-07	13	86.7

Pieris japonica ‘Mountain Fire’ (Forest Farm)	07-19-07	3:1	0.3K	4	09-25-07	2	50.0
Pieris japonica ‘Prelude’ (Briggs)	07-19-07	3:1	0.3K	8	09-25-07	6	75.0
Pieris japonica ‘Prelude’ (Cofer’s)	07-19-07	3:1	0.3K	14	09-25-07	11	78.6
Pieris japonica ‘Prelude’ (Forest Farm)	07-19-07	3:1	0.3K	10	09-25-07	9	90.0
Pieris japonica ‘Pygmaea’ (Forest Farm)	07-19-07	3:1	0.3K	11	09-25-07	8	72.3
Pieris japonica ‘Sarabonde’ (Briggs)	07-19-07	3:1	0.3K	25	09-25-07	20	80.0
Pieris japonica ‘Scarlet O’Hara’ (Briggs)	07-19-07	3:1	0.3K	10	09-25-07	8	80.0
Pieris japonica ‘Shojo’ (Briggs)	07-19-07	3:1	0.3K	8	09-25-07	7	87.5
Pieris japonica ‘Spring Snow’ (Briggs)	07-19-07	3:1	0.3K	12	09-25-07	10	83.3
Pieris japonica ‘Valley Fire’ (Forest Farm)	07-19-07	3:1	0.3K	14	09-25-07	7	50.0
Pieris japonica ‘Valley Rose’ (Briggs)	07-19-07	3:1	0.3K	8	09-25-07	3	37.5
Pieris japonica ‘Valley Rose’ (Forest Farm)	07-19-07	3:1	0.3K	12	09-25-07	6	50.0
Pieris japonica ‘Valley Valentine’ (Briggs)	07-19-07	3:1	0.3K	6	09-25-07	5	83.3
Pieris japonica ‘Valley Valentine’ (Forest Farm)	07-19-07	3:1	0.3K	10	09-25-07	4	40.0
Pieris japonica ‘Snow Drift’ (Briggs)	07-19-07	3:1	0.3K	18	09-25-07	18	100
Pieris japonica ‘Snow Drift’ (Forest Farm)	07-19-07	3:1	0.3K	27	09-25-07	26	96.3

Table 3.1.2 Rooting percentages of select *Pieris* taxa 12 September, 2007

Pieris accessions	Date of cuttings	Peat to perlite ratio	Rooting hormone (KIBA) rate	# cuttings made	Date removed from mist	# cuttings rooted	Rooting %
Pieris japonica 'Benihaja'	09-12-07	3:1	0.3K	16	11-20-07	11	68.8
Pieris japonica 'Bisbee Dwarf'	09-12-07	3:1	0.3K	16	11-20-07	6*	37.5
Pieris japonica 'Bolero'	09-12-07	3:1	0.3K	16	11-20-07	10	62.5
Pieris japonica 'Bonsai'	09-12-07	3:1	0.3K	16	11-20-07	15	93.8
Pieris japonica 'Chaconne'	09-12-07	3:1	0.3K	16	11-20-07	15	93.8
Pieris japonica 'Christmas Cheer'	09-12-07	3:1	0.3K	16	11-20-07	11	68.8
Pieris japonica 'Coleman'	09-12-07	3:1	0.3K	16	11-20-07	13	81.3
Pieris japonica 'Crimson Compact'	09-12-07	3:1	0.3K	16	11-20-07	10	62.5
Pieris japonica 'Cupido'	09-12-07	3:1	0.3K	16	11-20-07	16	100
Pieris japonica 'Daisen'	09-12-07	3:1	0.3K	16	11-20-07	7	43.8
Pieris japonica 'Debutante'	09-12-07	3:1	0.3K	16	11-20-07	12	75.0
Pieris japonica 'Firecrest'	09-12-07	3:1	0.3K	16	11-20-07	14	87.5
Pieris japonica 'Flamingo'	09-12-07	3:1	0.3K	16	11-20-07	12	75.0
Pieris japonica 'Havila'	09-12-07	3:1	0.3K	16	11-20-07	15	93.8
Pieris japonica 'Iseli Cream'	09-12-07	3:1	0.3K	16	11-20-07	10	62.5
Pieris japonica 'Kubas' (syn. 'Dubas')	09-12-07	3:1	0.3K	16	11-20-07	11	68.8
Pieris japonica 'La Rocaille'	09-12-07	3:1	0.3K	16	11-20-07	16	100
Pieris japonica 'Nocturne'	09-12-07	3:1	0.3K	16	11-20-07	14	87.5

Pieris japonica 'PI 418531'	09-12-07	3:1	0.3K	16	11-20-07	14	87.5
Pieris japonica 'Purity'	09-12-07	3:1	0.3K	16	11-20-07	13	81.3
Pieris japonica 'Pygmy'	09-12-07	3:1	0.3K	16	11-20-07	9	56.3
Pieris japonica 'Red Mill'	09-12-07	3:1	0.3K	16	11-20-07	11	68.8
Pieris japonica 'Sinfonia'	09-12-07	3:1	0.3K	16	11-20-07	14	87.5
Pieris japonica 'Stockman'	09-12-07	3:1	0.3K	16	11-20-07	11	68.8
Pieris japonica 'T40-82A'	09-12-07	3:1	0.3K	16	11-20-07	15	93.8
Pieris japonica 'T44-82U'	09-12-07	3:1	0.3K	16	11-20-07	15	93.8
Pieris japonica 'UNH'	09-12-07	3:1	0.3K	16	11-20-07	15	93.8
Pieris japonica 'Valentine's Day'	09-12-07	3:1	0.3K	16	11-20-07	12	75.0
Pieris japonica 'Valley Valentine' x 'Kubas'	09-12-07	3:1	0.3K	16	11-20-07	12	75.0
Pieris japonica 'Variegata'	09-12-07	3:1	0.3K	16	11-20-07	10	62.5
Pieris japonica 'Wada'	09-12-07	3:1	0.3K	16	11-20-07	6	37.5
Pieris japonica 'White Caps'	09-12-07	3:1	0.3K	16	11-20-07	14	87.5
Pieris japonica 'White Cascade'	09-12-07	3:1	0.3K	16	11-20-07	14	87.5
Pieris japonica 'White Water'	09-12-07	3:1	0.3K	16	11-20-07	0	0
Pieris japonica var. amamiana	09-12-07	3:1	0.3K	16	11-20-07	13	81.3
Pieris japonica x *Pieris floribunda* 'Spring Snow'	09-12-07	3:1	0.3K	16	11-20-07	13	81.3
P. japonica x P. formosa var .forestii 'Forest Flame'	09-12-07	3:1	0.3K	16	11-20-07	16	100
Pieris formosa var. forestii	09-12-07	3:1	0.3K	16	11-20-07	13	81.3

Table 3.2 *Pieris* propagation rooting percentages in two month intervals, 2009

Date of Cuttings	*Pieris* Accessions			
	Pieris japonica 'Temple Bells'	*Pieris japonica* 'Scarlet O'Hara'	*Pieris japonica* 'Snowdrift'	*Pieris phillyreifolia*
2/16/09	83.3%	94.4%	88.9%	50.0%
4/13/09	88.9%	100%	88.9%	77.8%
6/15/09	88.9%	94.4%	100%	83.3%
8/17/09	Mist House Failure	Mist House Failure	Mist House Failure	Mist House Failure
10/19/09	94.4%	88.9%	88.9%	72.2%
12/14/09	88.9%	88.9%	83.3%	83.3%

CHAPTER 4

CONCLUSIONS

The evaluations of the *Vitex* collection for a number of vegetative and reproductive traits over the course of two seasons and two years apart, showed interesting trends in terms of specific trait correlations. In general, vegetative traits between years (both container and in-ground) had higher correlations than either first-year vegetative to third-year floral data as well as first-year floral data to either third-year floral and vegetative traits. The data strongly suggest that trait correlations are stronger between the two in-ground treatments and that the use of first-year container data to predict future in-ground performance is not advisable.

While the correlation tables provided some keen insight into the relatedness of paired traits, there were somewhat contradictory results when the straight rankings of the top twenty accessions in select-first year traits were presented next to the same accessions' ranks in the third year. Many times the top twenty accessions of a particular trait had their ranks climb into the hundreds by the third year suggesting that it may be difficult or unwise to simply pick the top twenty (in this case) for future evaluations or as possible parents in subsequent generations. The rankings did show more consistency or less variability between the in-ground treatments, however. Attempts to tease out percentile rank correlations to determine how much of the *Vitex*'s first-year population would need to be collected (top ten percent, top twenty-five percent, e.g.) before a threshold percentage would also be contained in the third year's top ten or twenty-five percent was unsuccessful.

In summary, in-ground evaluations provided greater and more consistent correlation values than first-year container to third-year in-ground. Average inflorescence length, however, did show moderate correlations between first-year container data and the third-year treatment suggesting that this might be the only floral or reproductive traits that breeders may want to try and select for in containers. The correlation values, whether Pearson or Spearman however, do not give a complete picture on the probability or efficacy of selecting for superior in-ground performance of mature plants based on first-year data. The comparative ranks given for the end of year vegetative data as well as the selected reproductive data show that both container and in-ground ranks vary widely (and wildly) between the first and third years. Although there was still a general trend that demonstrated in-ground ranks were lower (and therefore better in this case) than container ranks when compared to the respective first year ranks, they were both sufficiently high or incongruent to rule out the ability to select for traits in containers or in-ground after just one season's growth.

With regards to the *Pieris* study, there is evidence to support the hypothesis that *Pieris* (at least select varieties) can be propagated effectively (>50% rooting and survivorship) throughout the year. The four varieties chosen for the full year propagations study may have better percentages than other taxa, and so also be the reason that there were greater stock plant quantities of these varieties. The rooting percentage in some instances may not be adequate from a commercial standpoint but they may be valuable for researchers who need relatively few clones on which to conduct experiments.