Japanese Snowbell Exhibits Variability for Time of Vegetative Budbreak and Susceptibility to Spring Freeze Damage

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Abstract. Japanese snowbell (Styrax japonicus Sieb. & Zucc.) is an outstanding small ornamental tree that is underused in the U.S. One of the reasons this Asian native is not more widely planted is that it is subject to spring freeze damage. The objectives of this study were to determine if there was variability within S. japonicus for time of budbreak and if this variability could be used for selecting plants better adapted to areas of the country that frequently experience late spring freezes. During Spring 1999 and 2000, budbreak was evaluated weekly in 224 open-pollinated seedlings. While weather conditions varied greatly between the 2 years, there was good consistency between 1999 and 2000 data. There was a 4-week difference between the earliest and latest plants to break dormancy. Based on the 1999 and 2000 data, 28 plants were selected and propagated. A replicated trial involving these selections and three cultivars was carried out in 2002, 2003 and 2004. All of the selections broke bud later and suffered less freeze damage than the cultivars ‘Emerald Pagoda’ and ‘Carillon’, but many performed similarly to ‘Pink Chimes’. Variation in height, width, caliper and canopy shape was observed among the selections. There is an opportunity to utilize the genetic variability in S. japonicus for developing cultivars with reduced susceptibility to spring freeze damage.

Styrax japonicus (Japanese snowbell) is a small deciduous tree that is cultivated as an ornamental. Native to Japan, China, Korea, Taiwan and the Philippines, it was introduced into the U.S. in 1862 (Dirr, 1998). The species grows from 6 to 9 m in height with a similar spread, making it a valuable plant for use in small residential landscapes or under utility lines. Flowers are bell-shaped, about 2 cm in diameter, and very fragrant. They are produced in midspring and hang beneath the foliage in three- to six-flowered racemes. Foliage is medium to dark green in summer and may turn yellow in fall. The species is generally pest free, even though problems with Ambrosia beetles, Xylosandrus spp., have been reported (C.E. Tubesing, 1990, D. Shadow, Shadow Nursery, personal communication). Styrax japonicus is rated as hardy to USDA cold hardiness Zone 5.

A few cultivars of S. japonicus are commercially available in the U.S. (Dirr, 1998; Raulston, 1991). ‘Issai’ is a fast-growing cultivar that that roots easily. ‘Carillon’ has a weeping plant habit and grows to only 2.5 to 4 m in height. ‘Pink Chimes’ is a pink-flowered selection that forms an upright shrub or small tree. These three cultivars were introduced to the U.S. from Japan. ‘Emerald Pagoda’ was collected in Korea and has leaves that are two to four times larger than typical for the species. A recent introduction, Snowcone (‘JFS-D’), was selected in the U.S. for its pyramidal growth habit and heavy flowering (J.F. Schmidt & Son Co., 2004). With the exception of ‘Pink Chimes’, all the aforementioned cultivars are white-flowered.

Despite its outstanding ornamental attributes, S. japonicus is not widely utilized in the U.S. Problems with branch dieback and lack of flowering have been reported for ‘Carillon’ and ‘Pink Chimes’ (Dirr, 1998; Meyer, 1992). Spring freeze damage to foliage is a common problem in the South (personal communication; Don Shadow, Shadow Nursery, Winchester, Tenn.; Rick Crowder, Hawkesridge Nursery, Hickory, N.C.). Considerable morphological and physiological variability has been reported in seedling populations of S. japonicus (Meyer, 1992; Raulston, 1991). The objective of this study was to determine if there was variability within this species for time of vegetative budbreak and if this variability could be exploited for developing cultivars with reduced susceptibility to spring freeze damage.

Materials and Methods

Evaluation of seedling populations. Two populations of open-pollinated seedlings, ranging in size from 15 to 61 cm, were planted at the Tennessee State University Nursery Research Center in McMinnville, Tenn. (USDA cold hardiness Zone 6b) in Spring 1998. The G258 population consisted of 122 plants obtained from Heritage Seedlings (Salem, Ore.), while the G259 population was comprised of 102 seedlings from Lawyer Nursery (Plains, Mont.). The field consisted of a Wayneboro silt loam with a pH of 5.5. Within-row spacing was 1.2 m and between-row spacing was 1.8 m. Plants were fertilized each spring at the rate of 57 kg ha⁻¹ N. Drip irrigation was provided as needed throughout the growing season.

Plants were evaluated in Spring 1999 and 2000 for budbreak, which was rated on a scale of 0 to 5, where 0 = 0%, 1 = 1% to 10%, 2 = 11% to 25%, 3 = 26% to 50%, 4 = 51% to 75%, and 5 = 76% to 100% of the buds on a plant having broken dormancy. A bud was considered to have broken dormancy when the overlapping bud scales had separated enough to reveal leaves. Plants were rated weekly for 6 weeks beginning when budbreak was first observed on any of the seedlings. Weekly budbreak ratings were averaged and Pearson’s correlation coefficient was calculated to determine the consistency of 1999 and 2000 ratings.

Evaluation of selections. Twenty-eight plants that exhibited delayed budbreak in both 1999 and 2000 were selected from the original 104 populations for further evaluation (Fig. 1). Selection was based primarily on low budbreak ratings, but other factors were also considered. Plants that had not flowered during either 1999 or 2000 were not selected, nor were any plants that appeared weak or unhealthy. A few plants with moderate budbreak ratings, but that flowered heavily both years of the study, were included among the selections.

The 28 selections, ‘Carillon’, ‘Pink Chimes’ and ‘Emerald Pagoda’ were propagated in Summer 2000. Softwood cuttings were dipped for 5 s in 19.6 mm indole-3-butyric acid in 50% ethanol, inserted into a 80% pine bark : 20% peatmoss (by volume) mixture and placed under mist. When roots developed, cuttings were transferred to 12.7-cm square pots containing pine bark amended with 6.6 kg m⁻³ 19N-2.1P-7.4K Osmocote fertilizer (Scotts-Sierra Horticultural Products Co., Maryville, Ohio), 0.6 kg m⁻³ Micromax (Scotts-Sierra Horticultural Products Co.) and 0.2 kg m⁻³ Epson salts. Rooted cuttings were maintained in an unheated greenhouse during Winter 2000-01. In Spring 2001, plants were transferred to 11.4 L containers using the pine bark potting medium described above and grown on a gravel-lined bed full in sun. Plants were irrigated using spray stakes.

In September 2001, the selections and cultivars were planted in the field in a randomized complete block with three single-plant replications. Within-row spacing was 3.6 m and between-row spacing was 3.5 m. Soil type, fertilization and irrigation were the same as described for the original seedling populations.

Plants were checked each time temperatures dropped below freezing during March and April 2002, 2003 and 2004. When freeze-damaged foliage was observed, damage was rated 2 to 3 days later on a scale of 1 to 5 with 1 = 0%, 2 = 1% to 10%, 3 = 11% to 25%, 4 = 26% to 50%, and 5 = 76% to 100% of a plant having damaged foliage. Because only very minor damage occurred to foliage as a result of freezing temperatures during Spring 2004, percent budbreak was used instead of damage ratings to compare plant.
temperatures of -6.7 °C were recorded on 22 Mar. 2002, at which time 98 GDD had accumulated since the first of the year. Considerable damage occurred to the foliage of 'Carillon' and 'Emerald Pagoda' (Table 2). Twenty-six of the selections and 'Pink Chimes' had not broken bud at the time of the freeze and were therefore undamaged. One selection, G259-45, suffered moderate freeze damage. Two plants each of 'Emerald Pagoda' and G258-98 died during Summer 2002. Therefore, this cultivar and selection were removed from the 2003 and 2004 statistical analyses.

In 2003, temperatures dropped to -3.3 °C on 22 Mar. Plants were further along in their development at the time of the freeze in 2003 than when the 2002 ratings were made, with 116 GDD having accumulated since the first of the year. Leaf damage ratings of the selections ranged from 1.0 to 4.0. With the exception of three selections (G258-60, G259-45, and G259-47), all selections had lower damage ratings than 'Carillon'. Statistically, none of the selections exhibited less damage than 'Pink Chimes'.

In 2004, temperatures dropped to -2.9 °C on 23 Mar. Only 89 GDD had accumulated prior to that freeze, and many of the plants had not broken bud. Since only minor damage was noted on the few plants that had leaves, leaf damage was not rated. Because no further freezing temperatures were experienced that winter, percent budbreak was rated on 9 Apr. 2004. At that time, 160 GDD had accumulated since the first of the year. Almost all of the buds on 'Carillon', but less than half of the buds on

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### Table 1. Vegetative budbreak during Spring 1999 and 2000 of 224 *Styrax japonicus* seedlings.

| Date       | Cumulative GDD | Budbreak\(^a\) (mean ± SE) | Plants with leaves(%) |
|------------|----------------|-----------------------------|-----------------------|
| 1999       |                |                             |                       |
| 18 Mar.    | 75             | 0 ± 0.01                    | 2.2                   |
| 25 Mar.    | 78             | 0.5 ± 0.08                  | 24.6                  |
| 1 Apr      | 85             | 1.3 ± 0.11                  | 52.0                  |
| 8 Apr.     | 129            | 3.6 ± 0.10                  | 94.6                  |
| 15 Apr.    | 165            | 4.9 ± 0.03                  | 100.0                 |
| 22 Apr.    | 205            | 5.0 ± 0.0                   | 100.0                 |
| 2000       |                |                             |                       |
| 29 Feb.    | 66             | 0.0 ± 0.01                  | 0.4                   |
| 7 Mar.     | 79             | 0.0 ± 0.01                  | 5.8                   |
| 14 Mar.    | 101            | 1.0 ± 0.08                  | 52.7                  |
| 21 Mar.    | 109            | 2.4 ± 0.11                  | 85.3                  |
| 28 Mar.    | 132            | 4.2 ± 0.08                  | 100.0                 |
| 4 Apr.     | 149            | 5.0 ± 0.01                  | 100.0                 |

\(^a\)GDD = Growing degree days = [(daily maximum temperature (°C) + daily minimum temperature (°C)) / 2] - 10. Cumulative GDD were compiled from January 1 until the end of the rating period each year.

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### Evaluation of seedling populations.

Budbreak was first observed in 1999 on 18 Mar. While half of the plants broke bud during the first two weeks of the evaluation, percent budbreak per plant increased only slightly during this time (Table 1). Warmer temperatures, as reflected in the accumulation of an additional 44 GDD, and a dramatic increase in percent budbreak, occurred between 1 Apr. and 8 Apr. There were still 11 seedlings, however, that had not broken bud by 8 Apr. Four weeks after the evaluations were initiated, >75% of the buds on all plants had broken dormancy.

As indicated by cumulative GDD, the weather in late February and early March 2000 was considerable warmer than during a similar period in 1999 (Table 1). In 2000, the first plant broke bud on 29 Feb., which was 18 d earlier than in 1999. By 14 Mar. 2000, half of the seedlings experienced budbreak to some extent, although percent budbreak per plant was low. A considerable increase in percent budbreak was observed between 21 Mar. and 28 Mar. 2000. As in 1999, there was a 4-week difference between the first and the last plants to break bud. Despite the different weather conditions, there was a highly significant, but moderate correlation (r = 0.62) between mean percent budbreak ratings in 1999 and 2000 (Fig. 1).
‘Pink Chimes’ had broken dormancy on that date. Percent budbreak was greater in ‘Carillon’ than in any of the selections, but only five selections (G258-60, G258-115, G258-117, G259-26 and G259-94) were slower to break bud than ‘Pink Chimes’.

Variation in growth rate and plant shape was observed among the selections (Table 2). Plant height ranged from 160 to 336 cm. These was also a 2-fold difference between the widest and narrowest selections. Caliper ranged from 39.9 mm to 73.5 mm. Growth index, which took into account both height and width, varied among the narrowest selections. Caliper ranged from 39.9 mm to 73.5 mm. Growth index, which took into account both height and width, varied from 136 to 244. For all measurements, ‘Pink Chimes’ was not significantly different from most of the selections.

**Discussion**

Buds of most temperate-zone deciduous trees and shrubs undergo a period of dormancy during the winter. Endodormancy involves factors within the bud itself and occurs during winter (Lang et al., 1987). Buds are not released from the endodormant state until a chilling requirement has been met (Saure, 1985; Sorensen, 1983). Ecodormancy is controlled by environmental factors and usually occurs in late winter and spring when dormancy is imposed by temperatures unfavorable for growth.

Time of budbreak is an important factor in nursery crop production. Early budbreak can result in a longer grower season and increased growth. However, in *S. japonicus*, early budbreak often leads to spring freeze damage to foliage. This study demonstrated that there is genetic variation within *S. japonicus* for time of vegetative budbreak. Even though strikingly different weather conditions were encountered in 1999 and 2000, there was good consistency between years as to whether a plant broke bud early or late in relation to the rest of the seedlings. Plants with even greater diversity in time of budbreak might be identified by evaluating larger populations from a wide range of native habitats, as provenance effects for the genetic variation in time of budbreak might be identified by evaluating larger populations from a wide range of native habitats, as provenance effects on time of budbreak have been found in red maple (Townsend, 1977) and pecan (Wood et al., 1998).

Replicated trials of plants that were selected on the basis of late budbreak indicated that the selections were considerably less susceptible to spring freeze damage than two popular cultivars, ‘Emerald Pagoda’ and ‘Carillon’. We are continuing the evaluation of plants identified in this study as having delayed budbreak to determine if they merit introduction as cultivars. Variation in growth measurements was observed among the selections, providing an opportunity to select for plants with different growth rates and forms. Using the genetic variability for physiological traits observed in this study and among *S. japonicus* growing in native stands (Meyer, 1992; Raulston, 1991) should lead to the development of cultivars with less susceptibility to damage from spring freezes and expand the use of this attractive tree in the landscape.

Further work is needed to identify the basis for the genetic variation in time of budbreak in *S. japonicus*. Genetic variation in chilling requirements needed to release plants from an endodormant state has been observed in a number of genera (Hauagge and Cummins, 1991; Wilson et al., 2002; Wood et al., 1998). Wilson et al. (2002) noted differences among red (Acer rubrum) and freeman (A. × freemani E. Murr. [rubrum × saccharinum]) maple cultivars not only for the number of hours below 7 °C needed to break endodormany, but also for the number of hours above 22 °C needed to initiate budbreak after the chilling requirement was met. While budbreak in *S. japonicus* appeared to be influenced by warm temperatures, as reflected in cumulative GDD, number of chilling hours accumulated during winter 1998–99 and 1999–2000 were not available for comparison. If genetic variation for both endodormancy and ecodormancy requirements exists in *S. japonicus*, then it may be possible to select plants suited for specific environments. For warmer climates, a low chilling unit requirement would ensure that endodormancy requirements are met even during mild winters while a high ecodormancy requirement would prevent budbreak until weather conditions were suitable for continued growth. In contrast, plants with a high chilling and a low heat unit requirement would perform

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**Table 2. Spring freeze damage, leaf development and growth measurements of Styrax japonicus selections and cultivars.**

| Plant        | Leaf damage| Budbreak | Ht | Width | Caliper | Growth index |
|--------------|------------|----------|----|-------|---------|--------------|
|              | 25 Mar. 2002 | 9 Apr. 2004 | (cm) | (cm) | (mm)   |              |
| G258-22      | 1.0 c       | 2.0 c     | 148 e | 268 e | 151 e  | 202 abed     |
| G258-33      | 1.0 c       | 2.0 c     | 323 c | 227 c | 129 c  | 168 bcede    |
| G258-34      | 1.0 c       | 2.0 c     | 331 a | 244 a | 152 a  | 211 abed     |
| G258-60      | 1.7 ed      | 1.5 ed    | 148 e | 244 a | 155 a  | 180 a-e      |
| G258-65      | 1.0 c       | 2.0 c     | 230 a  | 233 a | 172 a  | 207 abed     |
| G258-76      | 1.0 c       | 1.7 c     | 287 abd| 260 ab | 168 ab  | 198 a-e      |
| G258-84      | 1.0 c       | 1.7 c     | 336 a  | 260 ab | 180 ab  | 232 ab       |
| G258-87      | 1.0 c       | 1.7 c     | 335 a  | 260 ab | 164 a  | 220 ab       |
| G258-90      | 1.0 c       | 1.7 c     | 335 a  | 260 ab | 164 a  | 220 ab       |
| G258-98      | 1.0 c       | 1.7 c     | 335 a  | 260 ab | 164 a  | 220 ab       |
| G258-103     | 1.0 c       | 2.0 c     | 302 abc| 264 a | 124 cde | 170 bcede    |
| G258-115     | 1.0 c       | 1.3 c     | 302 abc| 264 a | 124 cde | 170 bcede    |
| G258-117     | 1.0 c       | 1.7 c     | 297 abd| 264 a | 124 cde | 170 bcede    |
| G259-16      | 1.0 c       | 2.7 c     | 160 e  | 131 bcede | 186 a-e     |
| G259-25      | 1.0 c       | 2.4 c     | 270 b  | 131 bcede | 186 a-e     |
| G259-26      | 1.0 c       | 1.0 c     | 302 abc| 131 bcede | 186 a-e     |
| G259-36      | 2.3 b       | 4.0 ab    | 217 cde| 130 bcede | 186 a-e     |
| G259-45      | 1.0 c       | 3.7 abc   | 270 a  | 130 bcede | 186 a-e     |
| G259-47      | 1.0 c       | 2.0 c     | 294 abd| 127 cde | 149 de    |
| G259-51      | 1.0 c       | 1.3 c     | 209 b  | 127 cde | 149 de    |
| G259-53      | 1.0 c       | 2.3 c     | 209 b  | 127 cde | 149 de    |
| G259-57      | 1.0 c       | 2.0 c     | 197 cde| 127 cde | 149 de    |
| G259-68      | 1.0 c       | 1.3 c     | 287 abcd| 115 cde | 172 ab     |
| G259-77      | 1.0 c       | 1.3 c     | 287 abcd| 115 cde | 172 ab     |
| G259-88      | 1.0 c       | 1.3 c     | 287 abcd| 115 cde | 172 ab     |
| G259-91      | 1.0 c       | 1.7 c     | 299 abd| 107 de | 168 abede  |
| G259-94      | 1.0 c       | 1.4 c     | 222 a  | 107 de | 168 abede  |
| Carillon     | 3.3 a       | 5.0 a     | 160 a  | 120 ede | 155 ede   |
| Pink Chimes  | 4.0 a       | 5.0 a     | 160 a  | 120 ede | 155 ede   |
| Emerald Pagoda| 4.0 a     | ---       | ---    | ---    | ---     | ---         |

1. Leaf damage rated on a scale of 1 to 5, where 1 = 0%, 2 = 1% to 10%, 3 = 11% to 25%, 4 = 26% to 50%, and 5 = >50% of the foliage damaged; ratings made 2 to 3 d after damaging freeze. Budbreak rated on a scale of 0 to 5, where 0 = 0%, 1 = 1% to 10%, 2 = 11% to 25%, 3 = 26% to 50%, 4 = 51% to 75%, and 5 = 76% to 100% of the buds having broken dormancy. Width = mean of in-row and perpendicular-to-row width measurements. Growth index = (height + width, in row + width, perpendicular to row)/3.

*Values within a column followed by the same letter do not differ significantly according to Tukey’s test (P < 0.05); n = 3.*
better in colder areas of the country. Plants identified in this study as differing in time of budbreak can serve as the basis for conducting a more detailed study on the genetic variation in dormancy requirements of *S. japonicus*.

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