# Plant Introduction, Distribution, and Survival: A Case Study of the 1980 Sino-American Botanical Expedition

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*The 1980 Sino-American Botanical Expedition (SABE) to the Shennongjia Forest District, Hubei Province, China, was the first botanical collecting trip by American scientists to that country since 1949. It was significant because the area visited had high species diversity and because the collected germplasm was widely distributed to a variety of botanical institutions throughout North America and Europe. This report documents the survival of this germplasm after 22 years of cultivation. Of the original 621 SABE collections, 258 are represented by plants growing in at least 18 different botanical institutions. The fact that 115 of these collections (45 percent) are represented by a single accession growing in a single location suggests that the plant introduction process is much more tenuous than has been generally assumed. This study also highlights the importance of data sharing among botanical institutions as the most effective way of determining the uniqueness of a given collection and assessing its environmental adaptability or invasiveness, or both, over a broad range.*

*Keywords: plant exploration; Shennongjia Forest District, China; collections' documentation; invasive species*

**Under the joint auspices of the Chinese Academy** of Sciences and the Botanical Society of America, the 1980 Sino-American Botanical Expedition (SABE) investigated the Shennongjia Forest District and the *Metasequoia* region of Lichuan Xian, in western Hubei Province, China. The expedition was remarkable for a number of reasons: (a) It was the first joint botanical collecting trip involving botanists from the United States and China since 1949; (b) the areas visited were of great botanical significance and high species diversity; (c) herbarium and germplasm collections were extensive, well documented, and accurately identified; and (d) living plants raised from seeds and cuttings collected during the expedition were widely distributed throughout North America and Europe (Dudley 1981, 1982, 1983a, 1983b, 1983c, Hebb 1982, Bartholomew et al. 1983a, 1983b).

The Shennongjia Forest District was selected as the primary site of the expedition because of the high diversity of its temperate flora. The district, which was established as a distinct administrative unit in 1970, is located in the northwestern part of Hubei Province. It occupies an area of approximately 3250 square kilometers and is situated at 31°15' to 31°57' N latitude and 109°56' to 110°58' E longitude (figures 1, 2). The mountains in the Shennongjia Forest District are oriented in a nearly west–southwest to east–northeast direction and have an average elevation of 1800 meters (m); Laojun Shan (2936 m), Xiaoshennongjia (3005 m), Dashennongjia (3052 m), and Wuming Shan (3105 m) are the highest peaks in the district (Bartholomew et al. 1983a).

Numerous scientific investigations of the Shennongjia Forest District have been conducted over the years; for an overview of these studies, see Bartholomew and colleagues (1983a). More recent botanical expeditions have examined the conservation status of specific taxa (Liu et al. 1999) and the status of various threatened plant communities (Deng et al. 2002, Jiang et al. 2002). Additional studies have documented the vegetable and crop germplasm resources of the area, including wild relatives and land races of economically important species (Liu and Du 1993).

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Because of its significance to botany and horticulture, we undertook a follow-up study of the 1980 SABE to document the present-day survival of the germplasm that was collected on the trip and its dispersal throughout the botanical gardens of North America and Europe. The broad goals of our survey were (a) to produce an inventory of living germplasm that is available for scientific research, (b) to evaluate the horticultural and curatorial factors that affected the survival of SABE collections after 22 years of cultivation, and (c) to develop a set of "best practices" that could be useful in the planning and execution of future expeditions, particularly with respect to the propagation and distribution of germplasm (Guarino et al. 1995). This article presents a summary of our survey results along with a brief discussion of their relevance to the issue of exotic invasive species (Mack et al. 2000, Reichard and White 2001, Baskin 2002).

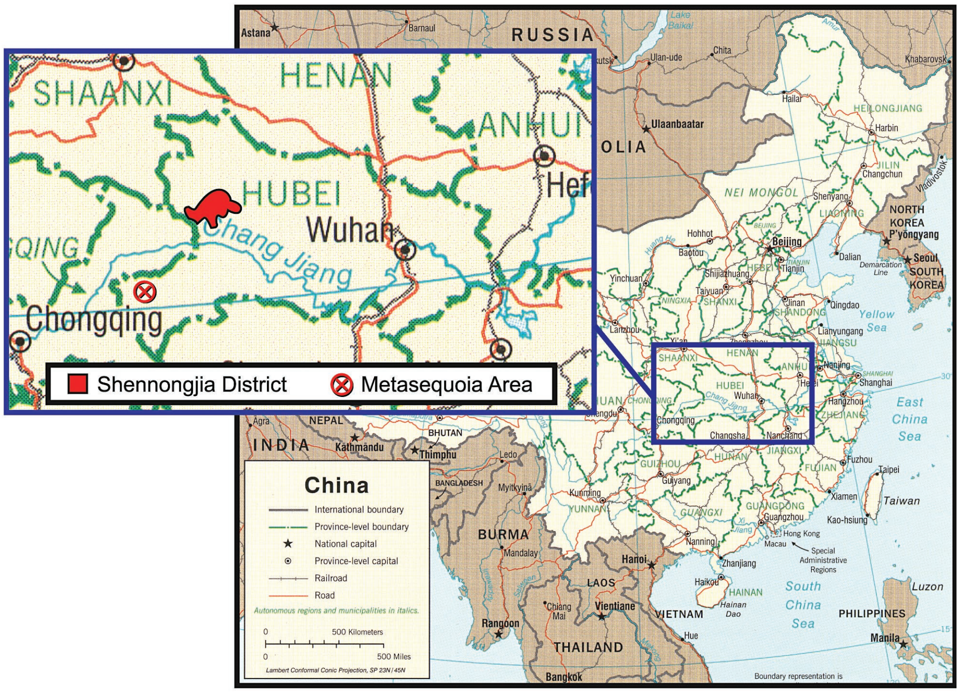


*Figure 1. Map of Asia, showing China, Hubei Province, the Shennongjia Forest District, and the* **Metasequoia** *region of Lichuan County.*

## Expedition overview

The SABE investigation took place from 15 August to 15 November 1980 and involved botanists from the Arnold Arboretum of Harvard University (Stephen A. Spongberg), the University of California–Berkeley (Bruce Bartholomew), the Carnegie Museum of Natural History in Pittsburgh (David E. Boufford), the United States National Arboretum (Ted R. Dudley), and the New York Botanical Garden (NYBG; James L. Luteyn). This group was accompanied in the field by Chinese botanists from the Institute of Botany, Beijing (Tang Yan-Cheng and Ying Tsun-Shen); the Jiangsu Institute of Botany, Nanjing (He Shan-An); the Wuhan Institute of Botany (Cheng Zhong, Jin Yi-Xin, Li Qing-Yee, Sun Siang-Chung, and Wan Jiz-Xiang); and the Kunming Institute of Botany (Chang Ao-Lo). Altogether, the expedition yielded 2085 collections of herbarium vouchers of vascular plants, 621 of which were also collected as germplasm. As is standard practice, each herbarium and germplasm collection was assigned a unique collection number, which referenced the location, habitat, and field information. This number was also used to document any postexpedition name changes, identifications, and evaluations.

In addition to the plants collected under the auspices of SABE proper, Bartholomew, Dudley, and Spongberg each made supplemental germplasm collections. Most of these were made shortly after the formal SABE exploration, during the course of visits to research institutes, botanical gardens,

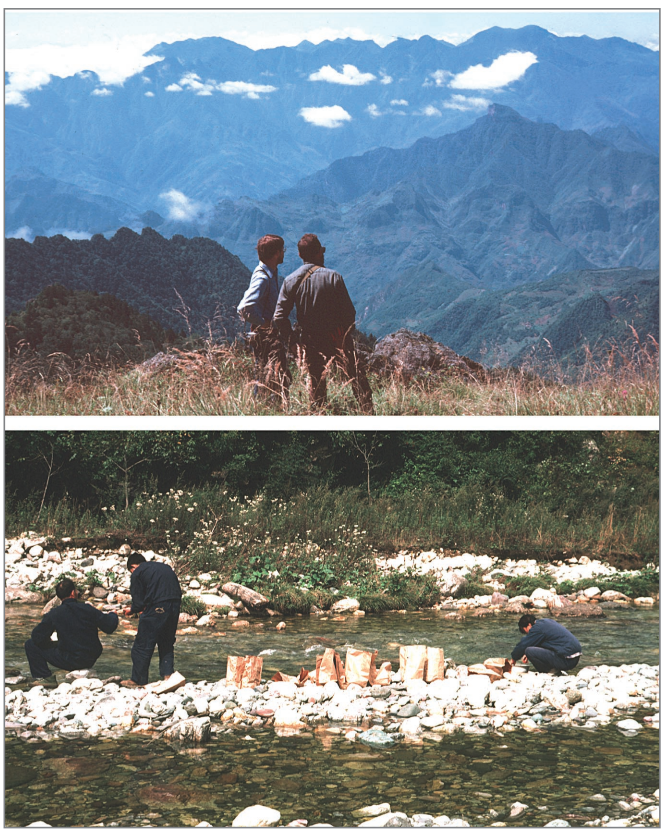

*Figure 2. Upper panel: An overview of the Shennongjia Forest District, Hubei Province, China, with Ted R. Dudley and James Luteyn in the foreground. Lower panel: Cleaning seeds in the river during the course of the 1980 Sino-American Botanical Expedition. Photographs: David Boufford.*

and scenic areas in several Chinese provinces. Between them, Dudley and Spongberg made 68 collections, mainly from cultivated plants, which we tracked using codes that included the collectors' initials, TRD and SAS, respectively (inventories are in the Arnold Arboretum Archives; Dudley 1983b). Bartholomew also made approximately 70 supplemental collections of plants potentially suited to the Mediterranean (etesian) climate of California, especially *Camellia* species (inventoried in the Arnold Arboretum Archives).

After the expedition ended, the germplasm was sent from China by diplomatic pouch to the US National Arboretum in Washington, DC, where about one-fourth was retained. The remaining three-fourths were distributed to the Arnold Arboretum of Harvard University; the University of California Botanic Gardens (UCBG), Berkeley; and NYBG's Cary Arboretum. After propagation at each of the four sites, the plants were integrated into the institutions' botanical collections and distributed to other botanic gardens, arboreta, and germplasm repositories.

Many of the plants collected during the course of SABE had unique botanical significance. Some were new to science or to cultivation, such as *Ilex shennongjiaensis* and *Sorbus yuana,* while others, such as *Stewartia sinensis* and *Sinowilsonia henryi,* had high conservation value (table 1). In addition, several plants of horticultural importance were introduced into cultivation, most notably *Heptacodium miconioides* (Koller 1986, Spongberg 1990), *Magnolia zenii* (Del Tredici and Spongberg 1989), *Pittosporum brevicalyx* 'Golden Temple' (Holm 2000), and *Rubus lasiostylus* var. *hubeiensis* (Schulhof 1990) (table 2, figure 3). Collections were also made of plants that, although not now part of the nursery trade to any significant degree, are under evaluation for their ornamental potential or are being used as a source of new genetic material for the improvement of species already in cultivation (table 2). Spongberg (1991) discussed several of these taxa after 10 years of cultivation and evaluation at the Arnold Arboretum.

## Historical precedents

Published accounts of botanical–horticultural expeditions are an integral part of the collection process. Written at some point after the trip is completed, these reports serve as a permanent record of the goals, methods, and results of the expedition, as well as a source of observations of the condition of the native habitats. Bretschneider (1898) summarized the early history of botanical exploration in China, and Sargent (1913–1917) documented the extensive collections that Ernest H. Wilson made in China while working for the Arnold Arboretum. The US Department of Agriculture (USDA) has a long history of introducing useful plants and documenting these collections in its publication about plant introductions. In the context of past botanical expeditions to China, the 1980 SABE trip reports produced by Dudley (1982, 1983a, 1983b, 1983c) and by Bartholomew and colleagues (1983a) set a high standard for documentation.

In contrast to trip reports, medium- to long-term follow-up evaluations of germplasm collections are less common, and many of those that have been published relate to the performance of species-specific, agronomic collections rather than to multispecies, nonagronomic collections. One such example is *Hevea* (rubber) germplasm collected in Brazil and evaluated for 10 years in Malaysia, with emphasis placed on the suitability of specific genotypes for culture and future breeding work (Huat et al. 1996). One of the most comprehensive evaluations of any germplasm expedition was conducted by Hymowitz (1984), who summarized the value of 4451 germplasm collections of soybean *(Glycine max)* and its relatives, gathered by P. H. Dorsett and W. J. Morse during their expedition to eastern Asia from 1929 to 1931. The study not only documented the availability of this germplasm 50 years after the expedition but also noted the contributions that specific collections had made to the improvement of the soybean crop.

In the realm of ornamental horticulture, medium- to

***Table 1. Extant Sino-American Botanical Expedition (SABE) and supplemental (SAS and TRD) germplasm collections of botanical significance.***

| Taxon | Collection type and number | Significance |
|---|---|---|
| *Betula fargesii* | SABE 904 | New to cultivation |
| *Celtis vandervoetiana* | SABE 1490 | New to cultivation |
| *Corylus mandshurica* | SABE 1535 | Disjunct population |
| *Heptacodium miconioides* | SAS 10, TRD 9A | CS: vulnerable; new to cultivation |
| *Ilex shennongjiaensis* | SABE 1554 | New species |
| *Liquidambar acalycina* | SABE 1950 | New to cultivation |
| *Magnolia zenii* | SAS 6, TRD 38A | CS: endangered; new to cultivation |
| *Malus baccata* | SABE 1298 | Unique and disjunct population |
| *Phoebe chekiangensis* | TRD 52A | CS: vulnerable |
| *Rubus lasiostylus* var. *hubeiensis* | SABE 114, 155 | New variety |
| *Sinojackia xylocarpa* | TRD 41A | CS: endangered |
| *Sinowilsonia henryi* | SABE 1483 | CS: rare |
| *Sorbus hemsleyi* | SABE 719, 1317, 1342 | New to cultivation |
| *Sorbus yuana* | SABE 1555 | New species |
| *Stewartia sinensis* | SABE 1568 | CS: vulnerable |
| *Taxus chinensis* | SABE 777, 1824 | Unique provenance |

CS, conservation status (according to Fu and Jin 1992); SAS, S. A. Spongberg; TRD, T. R. Dudley.

long-term follow-up reports on the survival, performance, and distribution of collections are rare. The Longwood Gardens–USDA Ornamental Plant Expedition program, which sponsored 13 trips to Asia between 1956 and 1970, produced well-documented collections but no follow-up studies on the fate of the germplasm (Tschanz 1977, Lighty 2000). Research reports from the USDA North Central Regional Plant Introduction Station, in Ames, Iowa, have assessed the survival and performance of plants collected from the former Yugoslavia (Widrlechner et al. 1992) and from northern Japan (Widrlechner et al. 1998), 10 years after their distribution to cooperators. There are also retrospective reports of the fate of germplasm collections made by specific individuals, such as Frank N. Meyer (Cunningham 1984), Wilson Popenoe (Rosengarten 1991), and Ernest H. Wilson (Farrington 1931), over the course of their careers, but they are far from comprehensive. Lighty (2000) undertook a cursory review of some recent (post-1970) botanical–horticultural expeditions, but the extent of his survey was very limited, and he did not track the collections of any specific expedition.

***Table 2. Extant Sino-American Botanical Expedition (SABE) and supplemental (SAS and TRD) germplasm collections of horticultural significance.***

| Taxon | Collection type and number |
|---|---|
| **Successfully introduced into cultivation as an ornamental** | |
| *Heptacodium miconioides* | SAS 10; TRD 9A |
| *Liquidambar acalycina* | SABE 1950 |
| *Magnolia zenii* | SAS 6; TRD 38A |
| *Pittosporum brevicalyx* 'Golden Temple' | SAS 26B |
| *Rubus lasiostylus* var. *hubeiensis* | SABE 0114, 0155 |
| *Saruma henryi* | SABE 1592 |
| *Sorbus yuana* | SABE 1555 |
| **Not yet introduced into cultivation but under evaluation** | |
| *Ilex fargesii* | SABE 1304, 1395, 1775 |
| *Ilex shennongjiaensis* | SABE 1554 |
| *Viburnum hupehense* ssp. *hupehense* | SABE 0241, 0630, 1733, 1766B |
| *Viburnum hupehense* ssp. *septentrionale* | SABE 1286 |
| **Represents new genetic material for improving taxa already in cultivation** | |
| *Acer davidii* | SABE 0517, 0536, 0679, 1125 |
| *Betula albo-sinensis* | SABE 0031 |
| *Cephalotaxus fortunei* | SABE 0751, 1038 |
| *Cephalotaxus sinensis* | SABE 1759, 1829 |
| *Corylopsis sinensis* | SABE 0752 |
| *Corylopsis sinensis* var. *calvescens* f. *veitchiana* | SABE 2033 |
| *Dipelta floribunda* | SABE 1611, 1684 |
| *Fragaria gracilis* | SABE 0164 |
| *Malus baccata* | SABE 1298 |
| *Malus halliana* | SABE 1218, 1314 |
| *Malus hupehensis* | SABE 0767 |
| *Sorbus hupehensis* | SABE 0879, 1315 |
| *Syringa reflexa* | SABE 0264, 0908 |
| *Taxus chinensis* | SABE 0777, 1824 |

SAS, S. A. Spongberg; TRD, T. R. Dudley.

## Survey methods

The first phase of our project was to compile a comprehensive list of all germplasm collections, arranged by the SABE collection number. Although a complete listing of all 2085 herbarium vouchers was published by Bartholomew and colleagues (1983a), the report did not indicate which collections included germplasm. This omission was rectified by Dudley (1982, 1983a, 1983b, 1983c), who presented the same voucher information as Bartholomew and colleagues but added a note indicating all germplasm collections. Subsequent research determined that Dudley's list of SABE germplasm collections was nearly complete and required only a few additions. We assembled the inventory of undocumented, supplemental germplasm collections made during the course of SABE from one of Dudley's published reports (1983b) and from written documents by Bartholomew and Spongberg (Arnold Arboretum Archives).

Once we compiled a complete list of germplasm collections, we queried our internal plant record database for all SABE and supplemental collections growing at the Arnold Arboretum and asked the three other institutions with germplasm from SABE (National Arboretum, UCBG, and NYBG's Cary Arboretum) to do the same. We also contacted some 30 other institutions in North America that we had reason to believe were maintaining plants that originated from SABE and asked if they could provide us with a list of those plants, regardless of their life-form status. We placed a notice in the March 2001 newsletter of the American Association of Botanical Gardens and Arboreta (AABGA) asking institutions that may have received any SABE germplasm to contact us. Finally, we made direct queries to several online, institutional plant record databases, such as the USDA Germplasm Resource Information Network, to locate material.


*Figure 3. A few plants of outstanding botanical and horticultural significance that were raised from seed collected during the course of the 1980 Sino-American Botanical Expedition (SABE). Samples coded SAS are from S. A. Spongberg's supplemental collection. (a) The chalky white stems of* **Rubus lasiostylus** *var.* **hubeiensis** *(SABE 155) stand out in the winter landscape of the Arnold Arboretum, Jamaica Plain, Massachusetts. (b)* **Stewartia sinensis** *(SABE 1568) in flower at the National Arboretum, Washington, DC. (c)* **Heptacodium miconioides** *(SAS 10) in fruit at the Arnold Arboretum. (d)* **Magnolia zenii** *(SAS 6) in flower at the Arnold Arboretum. (e)* **Sorbus yuana** *(SABE 1555) in flower at the Arnold Arboretum. Photographs: Peter Del Tredici.*

To gain additional insight on the germplasm during the propagation phase, we reviewed our own (Arnold Arboretum) propagation reports. We also examined our records of distribution following SABE. The National Arboretum undertook a similar project to locate and enter all of its SABE distributions into a database and generously shared its data with us. On the basis of distribution records from both arboreta, we contacted other botanical institutions, including many in Europe, that had received SABE plant material.

## Results

The complete inventory of SABE germplasm collections has been posted on the Arnold Arboretum institutional Web site *(www.arboretum.harvard.edu/plants/sabe.html)*. Of the 2085 SABE herbarium collections made, we determined that 621 were also collections of germplasm (579 collections of seed and 42 vegetative propagules or small plants), representing 402 unique taxa. The addition of 68 supplemental collections of 60 taxa made by Dudley and Spongberg brings the total yield of the expedition to 689 collections of 462 taxa (table 3). These numbers are in general agreement with those reported by Eisenbeiss (1982) in his description of the initial propagation of 732 germplasm collections. We believe that the higher number in Eisenbeiss's account has to do with the fact that some parcels of seed were subdivided in China before their shipment and were probably counted more than once.

The SABE germplasm collections were distributed among four of the American botanical institutions for propagation, with each receiving a selected subset of the total. Arnold Ar-

*Table 3. Number of collections of germplasm and taxa from the Sino-American Botanical Expedition (SABE) and supplemental collection trips.*

| Number | SABE | Supplemental (SAS and TRD) | Total |
|---|---|---|---|
| | Expedition | | |
| Initial count | | | |
| Collections | 621 | 68 | 689 |
| Taxa | 402 | 60 | 462 |
| Corrected count[a] | | | |
| Collections | 463 | — | 463 |
| Taxa | 310 | — | 310 |
| Presently alive | | | |
| Collections | 258 | 21 | 279 |
| Taxa | 187 | 21 | 208 |
| Single accession | | | |
| Collections | 115 | 15 | 130 |
| Taxa | 76 | 15 | 91 |

SAS, S. A. Spongberg; TRD, T. R. Dudley.

a. Corrected number of potentially living SABE collections and taxa, after accounting for those of questionable status.

boretum initially received 420 collections (followed by an additional 41), the National Arboretum received 496, NYBG's Cary Arboretum received 363, and UCBG received 407. The results of our survey indicate that, as of September 2002, 258 of the original 621 SABE collections (42 percent) are still alive in at least one North American or European institution (table 3). We were astonished to discover that nearly half of these collections (115 out of 258) are represented only by a single accession, and often only by a single plant. With respect to the 68 supplemental collections, 21 were alive as of September 2002; of these, 15 are represented as single accessions. At the level of distinct taxa, 187 of the 402 SABE collections are living (76 as single accessions), as are 21 of the 60 supplemental taxa (table 3).

Following the initial distribution of seed to the participating institutions, UCBG organized a distribution of excess seed (240 collections) to a select group of North American botanical institutions and individuals in early 1981 (memo from Bartholomew to Spongberg and Dudley, dated 12 December 1980, Arnold Arboretum Archives; Dudley 1981). Our survey results indicate that 134 of these collections (56 percent) are still alive.

## The propagation phase

At first glance, these survival percentages seem rather low, given that fewer than half of the taxa or collections brought back are still alive 22 years after the expedition and that approximately half are represented as single-plant accessions. These results, though technically accurate, fail to account for nonviable seeds and other difficulties that arose during the propagation phase (e.g., unknown germination requirements for unfamiliar taxa). One of us (P. D. T.) was the assistant plant propagator at the Arnold Arboretum when SABE was conducted and recorded which collections of seeds were hollow or rotten and which arrived in such low quantity that very few seeds germinated. Also, Eisenbeiss (1982) noted that most of the vegetative plant material (e.g., small plants, bulbs, and cuttings) failed to survive the 4- to 5-week transit from Asia to North America.

Relying on notations that accompanied the germplasm from China as well as notes in the Arnold Arboretum propagation records, we were able to assign questionable status to many collections. In addition, there were collections that were never received by the National Arboretum, despite being listed on inventories. We surmise that these were either confiscated at the time of inspection or discarded immediately on arrival at the National Arboretum. All told, we have determined that 158 of the 363 SABE collections that are no longer living were of questionable viability to begin with. Subtracting these from the original total, we calculated the corrected total of potentially extant SABE collections at 463, of which 56 percent (258) are presently alive. Using this same figure, 60 percent (187) of the potentially extant taxa are presently accounted for (table 3). We use these corrected values for our interpretation and discussion in this report. It is impossible to say how these figures compare with those from other collecting trips, given that accounts of comparable data sets have not been published.

It is obvious that generating living plants from seeds or vegetative propagules is a necessary step in the introduction process. Of the 247 SABE collections that the Arnold Arboretum successfully propagated, most (70 percent) are currently alive. Most of these collections were distributed in duplicate, which undoubtedly contributed to the high success rate. Within the botanical garden community, it is generally recognized that secondary distribution is the best way to compensate for unpredictable survival rates: Plants that fail to survive at one institution often flourish at another. Such differential survival may result from cultural practices in the greenhouse, environmental conditions in the outdoor nursery, or just plain luck.

## The distribution phase

Just as the propagation records proved of great value and allowed us to better understand the fate of the collections at that stage, the same could be said for the records covering the distribution of living plants. All decisions relating to the distribution of seedlings raised from the SABE collections were left to the individual institutions. Depending on the success of its propagation efforts, each of the four institutions decided how many plants from each collection it would keep for its own needs and what would be done with any excess. A memo from Spongberg to the Arnold Arboretum staff (dated 7 October 1981, Arnold Arboretum Archives) concerning distributions can perhaps be seen as typical for all parties involved. According to the memo, plants in excess of the Arnold Arboretum's needs "will be distributed to the other American institutions that participated in the expedition, and...[will be made] available to a select list of arboreta and gardens.... Those seedlings that remain after filling the requests from the select list will be made available to the New York Botanical Gardens' Cary Arboretum for winter storage. Next year [1982], they will be made available, along with the excess grown by the Cary Arboretum, in a joint Arnold Arboretum–Cary Arboretum distribution during the annual meeting of the American Association of Botanical Gardens and Arboreta, which will take place next spring at the Cary Arboretum."

More than 3300 plants from 85 different SABE and supplemental collections were offered to the attendees of the 1982 AABGA meeting in Millbrook, New York (Hebb 1982). As far as anyone can tell, the plants were simply put on tables, and people were allowed to freely take what they wanted. Unfortunately, no records were kept of what plants were taken or by whom. We have determined, however, that 63 of the 85 collections distributed at the meeting are still alive, in some cases perhaps only because of that distribution. At the time of the AABGA distribution in 1982, NYBG was in the process of redefining its relationship with the Cary Arboretum (which became the semiautonomous Institute for Ecosystem Studies the next year). As a result of this administrative change, very few SABE plants ended up being planted on the grounds of either the Cary Arboretum or NYBG. Indeed, this survey failed to detect a single living SABE accession at either institution. It appears that the majority of the NYBG quarter-share of the SABE germplasm was distributed to participants at the AABGA meeting.

Internal records show how the distribution process has been instrumental in helping to maintain living germplasm collections. According to the Arnold Arboretum records, 90 SABE collections and 25 of Spongberg's supplemental collections were initially selected for distribution by the Arnold Arboretum to interested parties. At present, 74 (82 percent) of the 90 SABE plants distributed by the Arnold Arboretum are accounted for as part of the living collections of the Arnold Arboretum or another institution. A similar percentage is found at the National Arboretum, where, of the 169 collections distributed, 133 (79 percent) are currently living. Of the 68 supplemental collections made by Dudley and Spongberg, we know that 38 were distributed by either the Arnold Arboretum or the National Arboretum and that 22 of these (58 percent) are alive today. Table 4 summarizes the number of SABE accessions we were able to locate in North American and European botanical institutions.

Regardless of how well an individual collection may be maintained at a given garden or arboretum, the distribution of duplicate seedlings (or vegetative propagules from those seedlings) greatly increases the chances that the collection will survive. To illustrate this point, one can look at what happens when material is not distributed. At the Arnold Arboretum, of the 74 SABE collections that are no longer alive yet were successfully propagated, 58 were never distributed (most often because of insufficient quantities). This observation suggests that individual germplasm collections that produce only a few plants should be given higher propagation priority than those that produce many plants.

Though distribution is one key to successful introduction, maintenence of distribution records is equally important. Without these records, it is nearly impossible to determine what material exists and where it may be located. This is demonstrated by the fact that 22 of the 85 SABE and supplemental collections distributed at the 1982 AABGA annual meeting were not detected during our survey. It is likely that some of these lost collections are alive somewhere, unrecognized by their curators. For institutions that distribute germplasm as part of their normal work, there is clear long-term value in documenting what plants have been distributed to whom and in making sure that a complete collection report accompanies the material. This step is particularly critical when material transfer agreements or memoranda of understanding that relate to the Convention on Biological Diversity are a required part of the distribution.

### Implications for curators and managers of genetic resources

The SABE living collections survey shows that the processes of germplasm collection and its subsequent propagation and distribution are much more tenuous than has been generally assumed. At present, only 42 percent of the original SABE collections are still alive after 22 years. Correcting this figure for seeds and cuttings that were of questionable viability, the figure is still a relatively low 56 percent. Most surprising was the discovery that nearly half of the surviving SABE collections are represented by a single accession growing in a single botanical institution. This figure suggests that botanical gardens and arboreta can be rather conservative when it comes to the distribution of wild, collected germplasm. For example, one of the species new to science and described and introduced by the 1980 SABE, *I. shennongjiaensis,* is currently represented in only two of the surveyed institutions, and in both cases it is represented only by staminate individuals.

The process of conducting the SABE living collections survey illustrates the importance of preserving the original collection number. Though some gardens were curating material that they suspected came from SABE, they had no record of the original SABE collection number. If it was a taxon for which there was only one collection, we could reestablish the SABE collection number and its associated provenance data. If the taxon was in more than one collection, it was impossible to reassign the original number, even though we were certain that the plant originated from the trip. In contrast, there were several instances in which the only information in an institutional accession record was the SABE collection number, and for these cases we were able to supply updated nomenclature and habitat information with ease.

By examining the combined records from all institutions, we were able to determine which collections were unique in cultivation (i.e., were represented by a single accession in a single garden). This was a significant contribution to the process of germplasm conservation, given that curators have no way of evaluating the uniqueness or rarity of their own col-

*Table 4. The number of distinct Sino-American Botanical Expedition (SABE) and supplemental (SAS and TRD) accessions currently growing in North American and European botanical gardens, arboreta, or other germplasm repositories.*

| Institution name and location | Number of SABE accessions | Number of supplemental accessions |
|---|---|---|
| Arboretum of the Royal Veterinary and Agricultural University, Copenhagen, Denmark | 14 | |
| Arnold Arboretum of Harvard University, Jamaica Plain, Massachusetts | 92 | 4 |
| Cornell Plantations, Cornell University, Ithaca, New York | 1 | 1 |
| Gothenburg Botanic Garden, Gothenburg, Sweden | 3 | |
| Holden Arboretum, Mentor, Ohio | 14 | |
| Morris Arboretum, University of Pennsylvania, Philadelphia | 20 | 1 |
| Morton Arboretum, Lisle, Illinois | 7 | |
| National Clonal Germplasm Repository, USDA, Corvallis, Oregon | 1 | |
| Plant Genetic Resources Unit, USDA, Geneva, New York | 9 | |
| Royal Botanic Gardens, Kew, Richmond, England | 33 | 2 |
| Royal Horticultural Society, Wisley, England | 1 | |
| Saratoga Horticultural Foundation, Saratoga, California | | 1 |
| Strybing Arboretum, San Francisco, California | 2 | |
| US National Arboretum, Washington, District of Columbia | 117 | 19 |
| University of British Columbia Botanical Garden, Vancouver, British Columbia, Canada | 41 | |
| University of California Botanical Garden, Berkeley, California | 102 | |
| Washington Park Arboretum, Seattle, Washington | 11 | |
| Woody Plant Germplasm Repository, USDA, Beltsville, Maryland | 1 | 2 |

SAS, S. A. Spongberg; TRD, T. R. Dudley; USDA, US Department of Agriculture.

lections without comparing them with the holdings of other institutions. The results of this survey clearly demonstrate that the sharing of collections' information is the only way to ensure the survival of unique germplasm. Indeed, as a result of our survey, a number of the single-accession SABE plants from a variety of institutions have been singled out for vegetative propagation and eventual distribution.

## Survey results and the issue of exotic invasive plants

We undertook the SABE living collections survey as a case study for assessing the medium- to long-term effectiveness of research-oriented germplasm introduction and distribution programs. Data from the survey have also shed light on the complex and contentious issue of native versus exotic invasive plants (Gould 1998, Mack et al. 2000, Mooney and Hobbs 2000, Reichard and White 2001, Sakai et al. 2001). Our results are in agreement with those reported by other authors, namely that a relatively small percentage of plant introductions become problematic invasives (Lowe 1998, Reichard and White 2001, Baskin 2002). This was also one of the conclusions stated in the declaration issued by the St. Louis Invasive Plants Species Workshop held at the Missouri Botanical Garden in February 2002, which was attended by representatives of various academic institutions, commercial nurseries, governmental agencies, and conservation organizations: "A small proportion of introduced plant species become invasive and cause unwanted impacts to natural systems and biological diversity as well as economies, recreation, and health" (see the Missouri Botanical Garden Other Links Web page for a link to this workshop; *www.mobot.org/MOBOT/other www.html).*

Many botanical gardens and arboreta now have established protocols for evaluating the invasive potential of plants in their living collections. Although it is true that botanical gardens and arboreta have played a role in the initial introduction of some invasive species, it is the widespread distribution of these species (especially woody ones) by governmental agencies and commercial nurseries that has increased both the scale of the problem and the speed of the species' spread (Reichard and White 2001). Of particular significance are the various federal- and state-sponsored programs in soil conservation, highway-bank stabilization, and wildlife cover that started in the 1930s and continue today (Zak et al. 1972, Luken and Thieret 1997, Westbrooks 1998). Well-known examples of plants that were used for such purposes and mass-planted by the millions in eastern North America include *Celastrus orbiculatus* (oriental bittersweet), *Elaeagnus* spp. (Russian and autumn olives), *Lonicera* spp. (Asian honeysuckles), *Melaleuca quinquenervia* (paperbark tree), *Pueraria lobata* (kudzu), *Rhamnus frangula* (glossy buckthorn), and *Rosa multiflora* (multiflora rose). These taxa represent some of the most noxious and problematic woody weeds. Commercial nurseries have also contributed to the problem by selling large quantities of common ornamentals such as *Acer platanoides* (Norway maple), *Berberis thunbergii*

(Japanese barberry), *Euonymus alatus* (winged euonymus), and *Hedera helix* (English ivy), all of which have naturalized in eastern North America.

As far as we have been able to determine—and, given the lag time between introduction and establishment (Kowarik 1995, Sakai et al. 2001), 22 years may not be long enough to tell—none of the plants introduced by the 1980 SABE have been found to become invasive. This includes the new introductions distributed as ornamentals (table 2) and two potentially aggressive herbaceous species *(Anemone hupehensis* and *Stylophorum lasiocarpum).* Ironically, at least three taxa known to be aggressive *(Clerodendrum trichotomum, Lonicera maackii* f. *maackii,* and *Polygonum cuspidatum)* are currently represented only by a single living accession. Judging from our survey of SABE germplasm survival, the larger problem for many botanical institutions seems to be keeping the plants alive rather than preventing them from escaping.

Given the low likelihood that a new plant introduction will become a problematic invasive, it is important that the botanical garden and arboretum community, along with the conservation community, make every effort not to throw out the (research) baby with the (invasive) bath water. We must not lose sight of the intrinsic value that plants of documented wild origin possess, regardless of their potential to naturalize in a given habitat. The botanical and horticultural literature is replete with studies that rely on documented wild-origin plants, particularly in the areas of systematics, breeding, and physiological ecology. Recent research based in part on living SABE collections has been done by Bell and colleagues (2001), Benson and colleagues (2001), and Donoghue and colleagues (2001).

It is self-evident that there is an ongoing need for botanical gardens and arboreta to continue introducing and growing new species for research purposes, including evaluation for invasiveness. It is also clear that these institutions are ideally suited to such evaluation, given their confined areas of cultivation, their conservative approach to distribution, their noncommercial orientation, and their long-term commitment to record keeping, data collection, and research. Short of banning the introduction of all new exotic species into North America, there is no effective alternative to the type of long-term evaluation currently practiced by most research-oriented botanical gardens, arboreta, and USDA germplasm repositories.

Rather than discouraging botanical gardens from introducing new plants, it would be far better to encourage initiatives that would standardize procedures for evaluating the plants' invasive potential (Baskin 2002). Preliminary steps in this direction have been outlined in the work of Mack (1996) and Reichard and Hamilton (1997). More recently, Widrlechner and Iles (2002) have developed a model for predicting the invasive potential of exotic plants on the basis of climate and geographic data. Although their study was specific for the central midwestern United States, their methods should be adaptable to other parts of the world. All of the above-mentioned authors emphasize the need for linking any predictive model to the ongoing field monitoring of invasive species over space and time, an approach also advocated by Boufford (2001). Clearly, there are no easy solutions to the problems posed by invasive species, but careful record keeping and documentation, together with observations in the wild and in controlled cultivation areas, will go a long way toward helping to manage them.

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