Diversity and Distribution of Isozymes in a \textit{Schlumbergera} (Cactaceae) Clonal Germplasm Collection

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\textbf{Abstract.} A germplasm collection of 59 \textit{Schlumbergera} Lemaire clones was assayed for isozymes of aspartate aminotransferase, glucose-6-phosphate isomerase, leucine aminopeptidase, malate dehydrogenase, phosphoglucomutase, shikimate dehydrogenase, and triosephosphate isomerase. The collection included cultivars of holiday cactus (\textit{S. truncata} (Haworth) Moran and \textit{S. \times buckleyi} (T. Moore) Tjaden) plus accessions of \textit{S. kautskyi} (Horobin & McMillan) N.P. Taylor, \textit{S. opuntioides} (Löfgren & Dusén) D. Hunt, \textit{S. orssichiana} Barthlott & McMillan, \textit{S. russelliana} (Hooker) Britton & Rose, \textit{S. \times exotica} Barthlott & Rauh, and \textit{S. \times reginae} McMillan & Orssich. Twelve loci with 36 alleles were detected. Percent polymorphic loci, mean number of alleles per locus, and mean heterozygosity were 83, 3.00, and 0.24, respectively, for the entire collection. Forty-one clones (69\%) could be distinguished solely on the basis of their isozyme profiles, but the remaining 18 clones shared profiles with one or two other clones. Isozymes proved useful for determining the parentage of some clones and verifying that some progeny were interspecific hybrids. About 28\% of the genetic diversity within the entire collection is unique to four \textit{Schlumbergera} species that have scarcely been exploited for breeding holiday cactus cultivars.

The genus \textit{Schlumbergera} is comprised of six species of epiphytic or epilithic shrubs native to southeastern Brazil (Barthlott and Taylor, 1995; Hunt, 1969). The genus can be divided into two groups based on vegetative characters. \textit{Schlumbergera kautskyi} (Horobin & McMillan) N.P. Taylor, \textit{S. orssichiana} Barthlott & McMillan, \textit{S. russelliana} (Hooker) Britton & Rose, and \textit{S. truncata} (Haworth) Moran have flattened, crenate or truncate phylloclades with areoles confined to the margins and apices, whereas \textit{S. microsphaerica} (K. Schumann) Hövel and \textit{S. opuntioides} (Löfgren & Dusén) D. Hunt have cylindric, terete or obovoid phylloclades with areoles distributed over the entire surface (Barthlott and Taylor, 1995). \textit{Schlumbergera truncata}, also known as crab cactus or Thanksgiving cactus, is the most commonly grown species in the genus and was introduced into cultivation around 1817 (Tjaden, 1964). The remaining five \textit{Schlumbergera} species are rare in cultivation. Three interspecific hybrids have been bred: \textit{S. \times exotica} Barthlott & Rauh (= \textit{S. opuntioides} \textit{x} \textit{S. truncata}); \textit{S. \times reginae} McMillan & Orssich (=\textit{S. orssichiana} \textit{x} \textit{S. truncata}); and \textit{S. \times buckleyi} (T. Moore) Tjaden (=\textit{S. russelliana} \textit{x} \textit{S. truncata}). \textit{Schlumbergera \times buckleyi}, better known as Christmas cactus, has been in cultivation since the 1850s (Hunt, 1981; Tjaden, 1964), whereas \textit{S. \times exotica} and \textit{S. \times reginae} are of relatively recent origin (Barthlott and Rauh, 1977; Horobin and McMillan, 1985) and are not cultivated extensively. Most of the 1,000+ \textit{Schlumbergera} cultivars in existence are either \textit{S. truncata} or complex \textit{S. \times buckleyi} hybrids (McMillan and Horobin, 1995). Thanksgiving cactus and Christmas cactus are known collectively as holiday cactus (Boyle, 1997).

Much of the germplasm resources within \textit{Schlumbergera} have not been exploited for breeding commercial cultivars (McMillan and Horobin, 1995). A \textit{Schlumbergera} clonal germplasm collection was assembled at the University of Massachusetts to serve as a resource for a breeding project. One of the project’s initial objectives was to develop a rapid and unambiguous means of identifying clones to minimize duplicate accessions in the collection. Presently, \textit{Schlumbergera} cultivars are distinguished by their phylloclade and flower morphology, flower color, growth habit, and flowering time under natural photoperiods (Barthlott and Rauh, 1977; Boyle, 1997; McMillan and Horobin, 1995). Most of these characters, however, are influenced by environmental conditions, thus limiting their usefulness for distinguishing cultivars. Additionally, fewer traits exist for identifying cultivars when plants are in a vegetative state. Isozymes have been used to identify cultivars in many crops (Nielsen, 1985; Weeden, 1989), including some cacti (O’Leary and Boyle, 1999). Typically, isozymes exhibit simple inheritance, codominance, complete penetrance, and consistent expression under a wide range of environmental conditions (Weeden and Wendel, 1989). Isozymes can also be used in plant breeding programs to verify hybridity and assess the level of genetic variation in germplasm collections (Weeden, 1989; Yndgaard and Hoskuldsson, 1985). Although \textit{Schlumbergera} exhibits considerable phenotypic variation (Barthlott and Rauh, 1977; Hunt, 1969), the extent of genetic variation in cultivated material remains unknown. The objectives of the present study were to: 1) ascertain the diversity and distribution of isozyme alleles in a collection of \textit{Schlumbergera} clones; and 2) determine if isozymes could be used to distinguish clones, identify duplicate accessions, elucidate pedigrees, and verify hybridity.

\textbf{Materials and Methods}

\textbf{Plant material.} Fifty-nine \textit{Schlumbergera} clones were included in this study. Most of the clones were holiday cactus cultivars, but accessions of \textit{S. kautskyi}, \textit{S. opuntioides}, \textit{S. orssichiana}, \textit{S. russelliana}, \textit{S. \times exotica}, and \textit{S. \times reginae} were also examined (Table 1). All \textit{Schlumbergera} species except for \textit{S. microsphaerica} were represented in the study. The holiday cactus clones surveyed included commercial cultivars (both contempo-
Table 1. Schlumbergera accessions used for study, and their isozyme phenotypes.

| Clone                  | Source¹ | Isozyme profile | Locus | Holiday cactus cultivars² |
|------------------------|---------|-----------------|-------|---------------------------|
| Abendroth No. 2        | DK      | 1 aa bb cc cd bb | Aat-1 |                         |
| Abendroth No. 6        | DK      | 2 aa bc bc bb bb bb cc | Aat-2 |                         |
| Abendroth No. 13       | DK      | 3 aa bb ac cc bb aa bb cd cd ab | Gpi-2 |                         |
| Alexis                 | GP      | 4 aa ab ab cc bb aa bb cc ed ab | Lap-1 |                         |
| Apricot                | DK      | 5 aa ab bc cc bb aa bb cc cc aa | Mdh-1 |                         |
| Barbara                | GP      | 6 aa cc ac cc bb aa bb cc cd ab | Mdh-2 |                         |
| Bridgeport             | CO      | 7 aa bc bb bb ab aa cc cc cc bb | Pgm-1 |                         |
| Cambridge              | CO      | 8 aa cc bc bb ab aa cc cc cc bb | Pgm-2 |                         |
| Christmas Cactus       | MA      | 5 aa ab bc cc bb aa bb cc cc aa | Slr-1 |                         |
| Christmas Charm        | CO      | 9 aa bc ab ab bb ab aa cc ee ab | Tpi-2 |                         |
| Christmas Cheer        | RG      | 10 aa bc bb bb ab aa cc cc ed ab |             |                         |
| Christmas Fantasy      | CO      | 11 aa bc ab ab bb ab aa cc cc cc bb |             |                         |
| Claudia                | GP      | 12 aa ab ab cc bb aa bb cc cc ab |             |                         |
| Dark Marie             | GP      | 13 aa bc bb cd bb aa bb cc cc bb |             |                         |
| Efra                   | JV      | 14 aa bb bb dd ab aa bc cc cc bb |             |                         |
| Gina                   | GP      | 15 aa bc bb bb bb ab aa bb cc cc bb |             |                         |
| Gold Charm             | CO      | 8 aa cc bc bb ab aa bc cc cc bb |             |                         |
| Huntington 50447       | HG      | 5 aa ab bc cc bb aa bb cc cc aa |             |                         |
| Kris Kringle           | CO      | 16 aa ab ab cc ab aa bb cc cd ab |             |                         |
| Kris Kringle II        | CO      | 17 aa ab bb cc ab aa dd cc ed bb |             |                         |
| Lavender Doll          | CO      | 18 aa ac ab bc bb aa bb cc cc bb |             |                         |
| Lavender Doll II       | CO      | 19 aa bc bb bb ab aa bd cc cd bb |             |                         |
| Lilofee                | DK      | 20 aa bc ab bd bb aa bc cc cd bb |             |                         |
| Linda                  | GP      | 21 aa ab bb bd ab aa bc cc ed bb |             |                         |
| Madisto                | GP      | 22 aa ac ab cd bb aa bb cc cc ab |             |                         |
| Madonga                | GP      | 23 aa bc ab cc bb aa bc cc cc bb |             |                         |
| Majestic               | DK      | 24 aa bc ab cd bb aa bc cc cd ab |             |                         |
| Marie                  | GP      | 13 aa bc bb cd bb aa bb cc cc bb |             |                         |
| Naomi                  | JV      | 25 aa cc bb dd bb aa bb cc ed bb |             |                         |
| Noris                  | DK      | 26 aa bc ab cc bb aa bb cc cc aa |             |                         |
| Peach Parfait          | CO      | 27 aa cc ab cc ab aa bc cc cc bb |             |                         |
| Pinkie                 | RG      | 22 aa ac ab ed bb aa bb cc cc ab |             |                         |
| Purple Devil           | DK      | 26 aa bc ab cc bb aa bb cc cc cc bb |             |                         |
| Red Radiance           | CO      | 28 aa ac aa cc bb aa bb cc cd bb |             |                         |
| Rocket                 | RG      | 29 aa bb bb bd bb aa bb cc cd bb |             |                         |
| Salomeune Rubrum       | DK      | 30 aa ac cc bb cc bb aa bb cc cc aa |             |                         |
| Santa Cruz             | CO      | 31 aa ab ab ab bb ab aa cc cc cd bb |             |                         |
| Sonja                  | JV      | 32 aa ac ab cd bb aa bd cc cd ab |             |                         |
| Starbrite              | LN      | 33 aa ab ab ab cc ab aa bc cc cc ab |             |                         |
| Thor-Britta            | GT      | 34 aa bb bb dd bb aa bb cc cc bb |             |                         |
| Thor-Louise            | GT      | 35 aa bc ab dd bb aa dd cc cc ab |             |                         |
| Twilight Tangerine     | CO      | 15 aa bc bb bb bb ab aa cc cc cc bb |             |                         |
| White Christmas        | CO      | 36 aa bb bb bb ab aa cc cc cc bb |             |                         |
| Yantra                 | JV      | 37 aa bb bb bb bb bb ab aa bb cc cc bb |             |                         |
| Zaraika                | JV      | 37 aa bb bb bb bb bb ab aa bb cc cc bb |             |                         |

Schlumbergera species and interspecific hybrids

| Species                  | Clone | Isozyme profile | Locus | Holiday cactus cultivars² |
|--------------------------|-------|-----------------|-------|---------------------------|
| S. ×exotica Exotica      | DK    | 38 ab bb bc ac ac bb aa ab cc ab |             |                         |
| S. ×exotica Minibelle    | RG    | 39 ab bb ab cc bb aa ad cc be ab |             |                         |
| S. kaatkii clonotype     | DK    | 40 ab bb bb dd bb aa bb cc ee bb |             |                         |
| S. opuntioides 01537     | BG    | 41 bb bb ab cc bb aa aa cc ab |             |                         |
| S. opuntioides RG clone  | RG    | 42 bb bb ab ac bb aa aa cc ab |             |                         |
| S. orssichiana AG clone  | AG    | 43 aa bd bb cd bb aa bb bc de ab |             |                         |
| S. orssichiana CO clone  | CO    | 43 aa bd bb cd bb aa bb bc de ab |             |                         |
| S. ×reginae 05584        | BG    | 44 aa bb bb bc ab aa bb cc ce ab |             |                         |
| S. russelliana 02636      | BG    | 45 aa bb bb cc bb aa bb cc cc bb |             |                         |
| S. russelliana 33160      | BH    | 46 ab bb aa cc cc bb aa bb cc cc aa |             |                         |
| S. russelliana 34533      | HG    | 47 aa bb bb dd bb aa bb cc ab |             |                         |
| S. russelliana Hunt 6484  | DK    | 48 aa bb bb cc bb aa bb cc cc aa |             |                         |
| S. russelliana IFH Clone 1| DK    | 49 aa bb bb cc bb aa bb cc cc aa |             |                         |

¹AG = Abbey Garden, Carpinteria, Calif.; BG = Botanischer Garten, Universität Bonn, Bonn, Germany; BH = Botanischer Garten, Universität Heidelberg, Heidelberg, Germany; CO = B.L. Cobia, Inc., Winter Garden, Fla.; DK = Dolly Kolli, Mashpee, Mass.; GP = Gartneriet PKM, Odense, Denmark; GT = Gartneriet Thoruplund, Odense, Denmark; HG = Huntington Botanical Gardens, San Marino, Calif.; JV = J. de Vries Potplantencultures, Aalsmeer, The Netherlands; LN = Leavitt’s Nursery, Lehighton, Pa.; MA = Univ. of Massachusetts, Amherst; RG = Rainbow Gardens, Vista, Calif.
²Clones of unknown parentage. Holiday cactus cultivars are either complex S. ×buckleyi hybrids or S. truncata selections.
Iszyme extraction, separation, and staining. Enzymes were extracted from phylloclade tissue. Isozyme extraction and separation procedures were described previously (O’Leary and Boyle, 1998a, 1998b). Native proteins were separated by polyacrylamide gel electrophoresis using a Mini-Protean II cell (Bio-Rad Laboratories, Hercules, Calif.). Single percentage (5% to 10%) gels were prepared using 0.375 M Tris-HCL (pH 8.8) as the gel buffer (Hames, 1981). The electrode buffer was 0.025 M Tris and 0.192 M glycine (pH 8.3) for all enzyme systems. Electrophoresis was conducted at 4 °C under constant voltage (200 V).

Seven enzyme systems were examined: aspartate aminotransferase (AAT, E.C. 2.6.1.1), glucose-6-phosphate isomerase (GPI, E.C. 5.3.1.9), leucine aminopeptidase (LAP, E.C. 3.4.11.1), malate dehydrogenase (MDH, E.C. 1.1.1.37), phosphoglucomutase (PGM, E.C. 5.4.2.2), shikimate dehydrogenase (SKD, E.C. 1.1.1.25), and triosephosphate isomerase (TPI, E.C. 5.3.1.1). Polyacrylamide gel concentrations and sample loading volumes were as follows: 5% gels and 10 µL for AAT; 7.5% gels and 10 µL for GPI, LAP, MDH, PGM, and SKD; and 10% gels and 5 µL for TPI. Gels were stained according to procedures of Wendel and Weeden (1989).

Mendelian inheritance was confirmed for the monomers LAP, PGM, and SKD in Schlumbergera (O’Leary and Boyle, 1998a) and for the dimers AAT, GPI, MDH, and TPI in the closely related genus Hatiora (O’Leary and Boyle, 1998b).

Data collection and analysis. Isozyme loci and allele designations were described in O’Leary and Boyle (1998a, 1998b). Percent polymorphic loci, mean number of alleles per locus, and mean heterozygosity were calculated separately for the following three groups: 1) the holiday cactus gene pool (= S. buckleyi and S. truncata clones) representing readily exploitable germplasm for cultivar development; 2) the Schlumbergera species gene pool (= S. kautskyi, S. opuntioides, S. orssichiana, and S. russelliana clones) comprising germplasm that has scarcely been used for breeding; and 3) all Schlumbergera clones. Mean number of alleles per locus and mean heterozygosity were calculated for all isozyme loci, monomorphic as well as polymorphic.

### Results and Discussion

Thirty-six alleles were detected among the 12 loci that were surveyed (Table 2). Gpi-1 and Mdh-3 were monomorphic but the other 10 loci were polymorphic. Among the polymorphic loci, the number of alleles per locus ranged from two (Aat-1, Mdh-1, Mdh-2, and Tpi-2) to five (Lap-1, Pgm-2, and Skd-1).

Several alleles were limited to one or a few clones. For example, alleles Lap-1e, Mdh-2b, Pgm-2a, and Pgm-2d were detected only in S. russelliana JFH Clone 1, Abendroth No. 6, Abendroth No. 2, and Abendroth No. 13, respectively (Table 1). Some alleles were restricted to specific taxa. Aat-2d occurred only in S. orssichiana and S. xreginae 05584, whereas Lap-1a, Pgm-1a, and Pgm-2e were detected only in S. opuntioides and S. xexotica (Table 1). Due to the paucity of authentic Schlumbergera species in this collection, it was not possible to discern taxonomic relationships within this genus using isozyme profiles. However, results suggest that isozymes may aid in distinguishing Schlumbergera species and therefore may be useful for resolving taxonomic questions about the genus.

A total of 49 isozyme profiles were identified among the 59 Schlumbergera clones (Table 1). Forty-one clones (69%) could be distinguished solely by their isozyme profiles. Among the 45 holiday cactus accessions, 30 (67%) displayed unique isozyme profiles. Eighteen Schlumbergera clones shared isozyme profiles with one or two other clones and could be classified into one of eight groups. Clones within six of these groups (profiles 5, 8, 12, 15, 26, and 37) could be distinguished from one another by other characters, i.e., morphological features, flower color, and/or growth habit. As expected, we were unable to distinguish sports using isozyme profiles. For example, the mutant ‘Dark Marie’ possessed the same isozyme profile as its parent (‘Marie’), but these two cultivars differed in flower and phylloclade pigmentation. Clones within two groups (profiles 22 and 43) were indistinguishable by isozymes or other characters, and probably represent identical clones.

Isozymes were used to address some questions of parentage. ‘Christmas Cactus’ (Table 1) is the clone that is grown commonly as a winter-flowering houseplant in the United States. ‘Christmas Cactus’ is intermediate between S. truncata and S. russelliana with

### Table 2. The relative mobility ($R_f$) of each allele scored in the isozyme survey of 59 Schlumbergera accessions. The $R_f$ values represent the means from three or more gels.

| Locus   | Allele | Mean $R_f$ | Locus   | Allele | Mean $R_f$ |
|---------|--------|------------|---------|--------|------------|
| Aat-1   | a      | 0.52       | Mdh-3   | a      | 0.36       |
|         | b      | 0.50       |         |        |            |
| Aat-2   | a      | 0.41       | Pgm-1   | a      | 0.64       |
|         | b      | 0.39       |         | b      | 0.59       |
|         | c      | 0.31       |         | c      | 0.56       |
|         | d      | 0.27       |         | d      | 0.54       |
| Gpi-1   | a      | 0.60       | Pgm-2   | a      | 0.47       |
|         | b      | 0.49       |         | b      | 0.45       |
|         | c      | 0.43       |         | c      | 0.40       |
|         | d      | 0.39       |         | d      | 0.37       |
| Lap-1   | a      | 0.60       | Skd-1   | a      | 0.47       |
|         | b      | 0.58       |         | b      | 0.44       |
|         | c      | 0.56       |         | c      | 0.39       |
|         | d      | 0.51       |         | d      | 0.37       |
|         | e      | 0.47       |         | e      | 0.35       |
| Mdh-1   | a      | 0.62       | Tpi-2   | a      | 0.38       |
|         | b      | 0.59       |         | b      | 0.33       |
| Mdh-2   | a      | 0.44       |         |        |            |
|         | b      | 0.42       |         |        |            |
Table 3. Distribution of isozyme alleles in four different groups of *Schlumbergera* accessions.

| Locus   | Truncata group | Intermediate group | Buckleyi group | *S. russelliana* clones |
|---------|----------------|--------------------|----------------|------------------------|
| Aat-1   | a              | a                  | a              | a,b                    |
| Aat-2   | a,b,c          | a,b,c              | a,b,c          | b                      |
| Gpi-2   | a,b,c          | a,b,c              | a,b,c          | a,b                    |
| Lap-1   | b,c,d          | b,c,d              | c              | c,d,e                  |
| Mdh-1   | a,b            | a,b                | b              | b                      |
| Mdh-2   | a,b            | a                  | a              | a                      |
| Pgm-1   | b,c            | b,c,d              | c              | c                      |
| Pgm-2   | a,c            | c,d                | c              | a,b,c                  |
| Skd-1   | c,d            | c,d                | c              | a,b                    |
| Tpi-2   | b              | a,b                | a              | a,b                    |

3 Refer to Table 1.
4 Truncata group cultivars (Abendroth No. 2, Abendroth No. 6, Bridgeport, Cambridge, Christmas Cheer, Christmas Fantasy, Dark Marie, Eva, Gold Charm, Marie, Peach Parfait, Rocket, Santa Cruz, Thor-Britta, Twilight Tangerine, and White Christmas) have truncate phylloclades, distinctly zygomorphic flowers that are held at an angle above a horizontal plane, yellow pollen, and terete pericarpels.
5 Intermediate group cultivars (Abendroth No. 13, Alexis, Barbara, Christmas Charm, Claudia, Gina, Huntington 50447, Kris Kringle, Kris Kringle II, Lavender Doll, Lavender Doll II, Lilofee, Linda, Madisto, Madonga, Majestic, Naomi, Pinkie, Red Radiance, Sonja, Starbrite, Thor-Louise, Yantra, and Zaraika) exhibit characteristics that are intermediate between the Truncata and Buckleyi groups.
6 Buckleyi group cultivars (Apricot, Christmas Cactus, Noris, Purple Devil, and Salomeone Rubrum) have truncate phylloclades, pendulous flowers rather than pure *S. truncata* and rather than pure *S. truncata* rather than pure *S. truncata*. Unfortunately, neither of the clones that Buckley used for hybridization are known to exist today. The isozyme data may shed some light on the origin of ‘Christmas Cactus’. Table 3 lists the distribution of isozyme alleles in four groups of *Schlumbergera* accessions: holiday cactus clones with *S. truncata*-like characters (=Truncata group), holiday cactus clones with *S. buckleyi*-like characters (=Buckleyi group), holiday cactus clones with characters that are intermediate between the Truncata and Buckleyi groups (=Intermediate group), and *S. russelliana* clones. The last group includes five of the seven known *S. russelliana* clones in cultivation (McMillan and Horobin, 1995). The most informative locus is Tpi-2. The five clones in the Buckleyi group and most of the seven *S. russelliana* clones have the Tpi-2a allele, whereas the 16 clones in the Truncata group are homozygous for Tpi-2b (Tables 1 and 3). These results suggest that Tpi-1a and Tpi-1b in holiday cactus originated from *S. russelliana* and *S. truncata*, respectively. If this hypothesis is true, then all clones in the Buckleyi group (including ‘Christmas Cactus’) could not be F₁ hybrids of *S. truncata* and *S. russelliana* because they are homozygous for Tpi-2a (Table 1). If ‘Christmas Cactus’ is in fact one of Buckley’s original hybrids, then it could be a BC₁ hybrid (*S. russelliana* x *S. buckleyi*) as Moran (1953) had suggested.

Isozymes were used to resolve two apparent cases of misidentification. Documentation provided with 05584 stated that it was the *S. orssichiana* clonotype, i.e., the original clone used to describe the taxon, but 05584’s phenotype suggested that it was a hybrid of *S. orssichiana* and *S. truncata* (=Reginae). A comparison of isozyme profiles for the authentic *S. orssichiana* clonotype (=AG clone) and 05584 indicates differences for Lap-1, Mdh-1, Pgm-2, and Skd-1. Hence, 05584 could not be the *S. orssichiana* clonotype. Also, three alleles (Lap-1b, Mdh-1a, and Skd-1c) that were present in 05584 were also common in holiday cactus, but these three alleles did not occur in AG clone (Table 1). These results support the contention that 05584 is a *S. reginae* hybrid. The second case concerned Huntington 50447, a field-collected plant that was identified as *S. truncata* by its collectors. However, its phylloclades and flowers were intermediate between *S. truncata* and *S. russelliana*. The Tpi-2 phenotype for

Table 4. Genetic diversity statistics for the holiday cactus clones, the *Schlumbergera* species clones, and for the entire *Schlumbergera* germplasm collection.

| Group         | Clones analyzed (no.) | Percent polymorphic loci | Mean no. alleles/locus | Mean heterozygozy |
|---------------|-----------------------|--------------------------|------------------------|-------------------|
| Holiday cactus| 44                    | 75                       | 2.17                   | 0.24              |
| Schlumbergera species | 9 | 67                | 2.25                   | 0.17              |
| All clones    | 56                    | 83                       | 3.00                   | 0.24              |

3 Calculations based on 12 loci.
4 Clones of *S. truncata* and *S. buckleyi* (see Table 1).
5 Duplicate accessions excluded from diversity calculations (see text).
6 Clones of *S. kautskyi*, *S. opuntioides*, *S. orssichiana*, and *S. russelliana* (see Table 1).
The presence of cactus (‘Minibelle’, and the two Russelliana ‘Minibelle’ are putative F1 hybrids of the holiday cactus clones and the of alleles per locus, and mean heterozygosity were 83, 3.00, and the holiday cactus clones. Percent polymorphic loci, mean number of isozymes will have practical value for identifying Schlumbergera cultivars and protecting breeder’s rights.

Among the 36 alleles that were surveyed, 17 were found in both the holiday cactus clones and the Schlumbergera species clones (=S. kautskyi, S. opuntioiides, S. orssichiana, or S. russelliana) but the remaining 19 alleles were limited to one of these two groups. Nine of the alleles occurred only in the holiday cactus clones whereas the other 10 alleles were restricted to the Schlumbergera species clones. Thus, about 28% of the genetic diversity within the entire collection is unique to four Schlumbergera species that have scarcely been exploited for breeding holiday cactus cultivars. Incorporating some or all of these Schlumbergera species into holiday cactus breeding programs may help broaden the genetic diversity of the crop and enhance efforts to develop novel cultivars for commercial use.

This study demonstrates that substantial isozyme polymorphism is present in the Schlumbergera germplasm collection. The high level of isozyme polymorphism enabled us to distinguish most cultivars, identify duplicate accessions, rectify cases of misidentification, and address questions of parentage. We anticipate that isozymes will have practical value for identifying Schlumbergera cultivars and protecting breeder’s rights.