

Assessment of Genetic Relationships among *Philodendron* Cultivars Using AFLP Markers

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ABSTRACT. *Philodendrons* (*Philodendron* Schott) are among the most popular tropical ornamental foliage plants used for interior decoration. However, limited information is available on the genetic relationships among popular *Philodendron* species and cultivars. This study analyzed genetic similarity of 43 cultivars across 15 species using amplified fragment length polymorphism (AFLP) markers with near infrared fluorescence labeled primers. Forty-eight *EcoR* I + 2 / *Mse* I + 3 primer set combinations were screened, from which six primer sets were selected and used in this investigation. Each selected primer set generated 96 to 130 scorable fragments. A total of 664 AFLP fragments were detected, of which 424 (64%) were polymorphic. All cultivars were clearly differentiated by their AFLP fingerprints, and the relationships were analyzed using the unweighted pair-group method of arithmetic average cluster analysis (UPGMA) and principal coordinated analysis (PCA). The 43 cultivars were divided into five clusters. Cluster I comprises eight cultivars with arborescent growth style. Cluster II has only one cultivar, ‘Goeldii’. There are 16 cultivars in cluster III, and most of them are self-heading interspecific hybrids originated from R.H. McColley’s breeding program in Apopka, Fla. Cluster IV contains 13 cultivars that exhibit semi-vining growth style. Cluster V has five cultivars that are true vining in morphology, and they have lowest genetic similarity with philodendrons in other clusters. Cultivated philodendrons are generally genetically diverse except the self-heading hybrids in cluster III that were mainly developed using self-heading and semi-vining species as parents. Seven hybrid cultivars have Jaccard’s similarity coefficients of 0.88 or higher, suggesting that future hybrid development needs to select parents with diverse genetic backgrounds.

The genus *Philodendron* contains more than 700 species (Croat, 1997), making it the second largest genus in the family Araceae (also referred to as aroids). *Philodendrons* are native to tropical America and comprise a conspicuous component of the native flora. All *Philodendron* species are open-pollinated as the flowers are unisexual in nature (Mayo et al., 1997). However, species differ widely in growth habits from climbing to arborescent, leaf sizes vary from small (10 cm long and 6 cm wide) to gigantic (120 cm long and 40 cm wide), leaf shapes from heartleaf to palm-like, and leaf colors from light yellow to burgundy (Croat, 1997; Grayum, 1996; Mayo, 1991). Thus, many philodendrons have been grown

as ornamental foliage plants (Huxley, 1994; Liberty Hyde Bailey Hortorum, 1976). In fact, *Philodendron* formerly dominated all other genera of tropical ornamental foliage plants, accounting for 50% and 36% of the national wholesale value of foliage plants in the United States in 1956 and 1967, respectively (Chen et al., 2002; McConnell et al., 1989). Based on their growth habits, philodendrons were divided into three groups by McColley and Miller (1965). The first group is the vining or scandent, such as *P. scandens* K. Koch & Sello (heartleaf philodendron); it is grown as either hanging baskets or containerized plants where vines are supported by totem poles. The second group has a self-heading and upright growing style, which is represented by *P. wendlandii* Schott. The third group is the erect-arborescent type, such as *P. bipinnatifidum* Endl., which appear self-heading when they are young, but assume more woody and treelike shapes as they are mature.

Documented hybridization within the genus *Philodendron* dates from 1887 in Florence, Italy (Wilfret and Sheehan, 1981). The first U.S. hybrid was developed by Manda in 1936 from the cross between *P. hastatum* C. Koch & H. Sello (now considered to be *P. domesticum* Bunt.) and *P. erubescens* K. Koch & Augustin (Bald, 1951). Since then, outstanding self-heading *Philodendron* hybrids with red, yellowish, or orange foliages have been released from R.H. McColley’s breeding program at Bamboo Nursery in Apopka, Fla. (Norris, 1987). McColley and

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Miller (1965) claimed that crosses of plants between either group could not be successful. Henny and Chen (2003) explained this might be due to the differences in chromosome numbers since $2n = 32, 34,$ and 36 were found in *P. scandens*, *P. wendlandii*, and *P. bipinnatifidum*, respectively.

Despite their importance as ornamental foliage plants, genetic relationships among *Philodendron* cultivars have not been determined. Amplified fragment length polymorphism (AFLP) is a PCR-based assay for plant DNA fingerprinting that reveals significant levels of DNA polymorphism (Vos et al., 1995). Molecular marker profiles based on AFLPs can be used to detect variation at the DNA level and have proven to be extremely effective in distinguishing closely related genotypes. Other advantages of this technique include reproducibility, high resolution, genome-wide distribution of markers, and no required prior knowledge of the genome being studied (Mueller and Wolfenbarger, 1999). The objectives of this study were to determine genetic relationships of common cultivars of *Philodendron* and to provide a genetic basis for future attempts in hybrid development and for conservation of *Philodendron* genetic resources.

Materials and Methods

PLANT MATERIALS. Forty-three *Philodendron* cultivars along with one cultivar each of five other ornamental foliage aroid genera [*Aglaonema* Schott, *Alocasia* (Schott) G. Don, *Anthurium* Schott, *Dieffenbachia* Schott, and *Spathiphyllum* Schott] were collected from the research greenhouses at the Univ. of Florida's Mid-Florida Research and Education Center (MREC), ornamental foliage plant nurseries in central Florida, and the Botanical Garden at the Univ. of California–Riverside (UCRBG) (Table 1).

FLUORESCENT-AFLP ANALYSIS. AFLP analysis was performed based on Chen et al. (2004a). Briefly, total DNA was extracted from young leaves using the DNeasy system (Qiagen, Valencia, Calif.). AFLP analysis was conducted using the GIBCO BRL AFLP System II (Life Technologies, Grand Island, N.Y.) and visualized with the LI-COR IR automated sequencer 4000-L (LI-COR, Lincoln, Nebr.). Total DNA (125 ng) from all samples was digested with 1 ml of mixture of *EcoR* I/*Mse* I (1.25 units/ μ L) at 37 °C overnight and ligated to *EcoR* I/*Mse* I adapters with 1.5 μ L (1 unit/ μ L) of T4 DNA ligase at 25 °C for at least 6 h. Pre-amplification reactions were performed on a MJR Cycle LR (MJ Research, Watertown, Mass.). The pre-amplified PCR product was quantified in the fluorometer, and the amount of template for subsequent PCR was diluted to 125 ng/ μ L⁻¹, and selective amplification was performed.

The selective amplification PCRs was performed by another touchdown program as described by Chen et al. (2004a). Both pre- and selective-amplification conditions were modified according to Myburg et al. (2000). The products from the selective amplification were electrophoresed on 25 cm \times 0.25 mm 8% denaturing polyacrylamide Long Ranger Gel Solution (BMA, Rockland, Maine) in 0.8 \times TBE buffer using a LI-COR automated sequencer 4000-L.

Initially, a total of 48 AFLP primers were screened, from which six primer sets (IRD700 E+TC/M+CAA; IRD800 E+AA/M+CAA; IRD700 E+TC/M+CAT; IRD800 E+AA/M+CAT; IRD700 E+GG/M+CAA; and IRD800 E+CC/M+CAA) that showed clear scorable and highly polymorphic fragments (Table 2) were selected for fluorescent-AFLP reactions with the samples of the 43 *Philodendron* cultivars and five aroid genera listed in Table 1.

DATA ANALYSIS. AFLP fragments were visually scored as present (1) or absent (0) to create the binary data set. The data was entered into a binary data matrix as discrete variables. Jaccard's coefficient of similarity (Sneath and Sokal, 1973) was calculated for all pair-wise comparisons among the 43 *Philodendron* cultivars and 5 other aroid genera as follows: $Jaccard = N_{AB} / (N_{AB} + N_A + N_B)$, where N_{AB} is the number of bands shared by two cultivars (A and B); N_A represents amplified fragments in cultivar A only and N_B represents fragments in cultivar B only. A dendrogram was generated by cluster analysis using the unweighted pair group method of the arithmetic averages (UPGMA). Principal coordinated analysis (PCA) was also carried out to show multiple dimensional distributions of the cultivars in a scatter-plot (NTSYS-pc, version 2.1) (Rohlf, 2000).

Results and Discussion

AFLP PROFILES AND ANALYSIS. Clear-cut AFLP profiles were generated by the six primer sets for the 43 *philodendron* cultivars and five other aroid genera, and each primer set generated identical fragment patterns for the duplicated cultivar 'Moonlight' (the duplicates came from separate DNA preparations). An example of fluorescent-AFLP profile of 30 *Philodendron* cultivars with one duplicated 'Moonlight' and five other aroid genera is shown in Fig. 1. Using the six selected primer combinations, a total of 664 scorable AFLP fragments were generated, of which 424 (64%) were polymorphic (Table 2). The fragments ranged from 50 to 650 bp with a majority of the polymorphism being distributed between 150 and 350 bp. On average, each primer set produced 110.7 fragments with 70.7 fragments being polymorphic. The level of polymorphism from this study is similar to that detected in other plants when AFLP techniques were used for measuring genetic variability. Aggarwal et al. (2002) identified 501 AFLP markers from basmati rice (*Oryza sativa* L.) with 65% of them being polymorphic. Chen et al. (2004a, 2004b) reported 69% polymorphism in *Aglaonema* and 71% polymorphism in *Dieffenbachia*, two other aroid genera.

GENETIC RELATIONSHIPS AMONG CULTIVARS. A dendrogram for the *Philodendron* cultivars and five other aroid genera was constructed based on the UPGMA analysis using Jaccard's coefficients of similarity (Fig. 2). The 43 cultivars are divided into five clusters. Clusters I, III, IV, and V contain arborescent, self-heading, semi-vining, and vining-type cultivars, respectively, whereas cluster II has only one cultivar 'Goeldii' whose stem is erect or hanging, sometimes tortuous.

Jaccard's similarity coefficients for cultivars in cluster I range from 0.48 to 0.70. 'Selloum' is a *P. bipinnatifidum* (formerly *P. selloum* C. Koch) and grown as a freestanding specimen in many container sizes and ultimately becoming woody and fairly erect. 'Selloum' is also grown in tropical or subtropical regions under shade as a landscape plant, and may spread to more than 3 m across. Generally, *P. bipinnatifidum*, native to Brazil, is hardy and able to tolerate a temperature close to freezing (Griffith, 1998). 'Xanadu' is a miniature form of 'Selloum' with a more compact appearance. 'Classic Xanadu', as its name indicates, resembles 'Xanadu'. 'Showboat' is a sport of 'Xanadu'. 'Hope' is selected from a self pollination of 'Selloum' and is more of a dwarf cultivar. 'Baby Hope' is a somaclonal variant of 'Hope'. The origin of 'Octopus' is unknown; it may also come from the same cross as 'Hope'. 'Williamii' is a *P. williamsii* Hook. Like 'Selloum', it is arborescent and native to Brazil.

All cultivars in the cluster I belong to *P. bipinnatifidum* except

Table 1. Backgrounds, growth habits, origins, and sources of 43 *Philodendron* cultivars and five aroid controls used in this study.

Cultivars	Background	Growth habit	Origin	Sources
101-1	Hybrid	Self-heading	Florida	UF/MREC ^z
102-4	Hybrid	Self-heading	Florida	UF/MREC
103-2	Hybrid	Self-heading	Florida	UF/MREC
104-3	Hybrid	Self-heading	Florida	UF/MREC
Angus ectifolium	<i>P. angustisectum</i>	Semi-vining	Colombia	Twyford, Inc. ^y
Autumn	Hybrid	Self-heading	Florida	UF/MREC
Baby Hope	Variant of 'Hope'	Arborescent	Florida	UF/MREC
Banda Birdnest Philly	Unknown	Vining	Unknown	Agri-Starts, Inc. ^x
Bituec	Hybrid	Self-heading	Florida	Agri-Starts, Inc.
Black Cardinal	Hybrid	Self-heading	Florida	UF/MREC
Burke Marx	<i>P. imbe</i>	Semi-vining	Brazil	Agri-Starts, Inc.
Classic Xanadu	<i>P. bipinnatifolium</i> Endl.	Arborescent	Unknown	UF/MREC
Ginny	Unknown	Vining	Unknown	Agri-Starts, Inc.
Goeldii	<i>P. goeldii</i>	Goeldii type	French Guyana	Twyford, Inc.
Greg Hambeli 1	Unknown	Semi-vining	Unknown	Twyford, Inc.
Greg Hambeli 2	Unknown	Semi-vining	Unknown	Twyford, Inc.
Greg Hambeli Sq Petiole	Unknown	Semi-vining	Unknown	Twyford, Inc.
Hope	Selfed <i>P. bipinnatifolium</i>	Self-heading	Florida	Twyford, Inc.
Hybrid Selloum	Unknown	Semi-vining	Unknown	Twyford, Inc.
Imperial Green	Hybrid	Self-heading	Florida	Twyford, Inc.
Imperial Red	Hybrid	Self-heading	Florida	Twyford, Inc.
Imperial Red Philo.	Hybrid	Self-heading	Florida	UCRBGw
Lime Tetraploid	Unknown	Self-heading	Unknown	UF/MREC
Moonlight	Hybrid	Self-heading	Florida	UF/MREC
Octopus	Unknown	Arborescent	Unknown	Twyford, Inc.
Panda	<i>P. bipennifolium</i>	Semi-vining	Brazil	Agri-Starts, Inc.
Pertusum	Unknown	Vining	Unknown	Agri-Starts, Inc.
Pinnatifidum	<i>P. pinnatifidum</i>	Semi-vining	Venezuela	Agri-Starts, Inc.
Pinnatifidum	<i>P. pinnatifidum</i>	Semi-vining	Venezuela	UCRBG
Princess of Orange	Hybrid	Self-heading	Florida	UF/MREC
Red Bristle	<i>P. pedatum</i> Kunth & Bouche	Semi-vining	Venezuela to Brazil	Agri-Starts, Inc.
Royal Queen	Hybrid	Self-heading	Florida	Agri-Starts, Inc.
Rudolph	Unknown	Semi-vining	Unknown	Twyford, Inc.
Sawtooth	Unknown	Self-heading	Unknown	Twyford, Inc.
Scandent	<i>P. scandens</i>	Vining	Mexico to Brazil	UF/MREC
Selloum	<i>P. bipinnatifolium</i>	Arborescent	Brazil	UF/MREC
Showboat	Sport of 'Xanadu'	Arborescent	Unknown	Twyford, Inc.
Sunset	Hybrid	Self-heading	Florida	UF/MREC
Sunshine	Unknown	Semi-vining	Unknown	UCRBG
Tahiti Green	Unknown	Semi-vining	Unknown	Twyford, Inc.
Variiegated Scandent	Sport of 'Scandent'	Vining	Unknown	Twyford
Williamii	<i>P. williamsii</i>	Arborescent	Brazil	Agri-Starts, Inc.
Xanadu	<i>P. bipinnatifolium</i>	Arborescent	Unknown	UF/MREC
Amazonica	<i>Alocasia lowii</i> Hook.f. x <i>A. sanderiana</i> Bull.	NA ^v	Unknown	Agri-Starts, Inc.
Red Hot	<i>Anthurium</i> ×	NA	Florida	UF/MREC
Treubii	<i>Aglaonema commutatum</i> Schott	NA	The Philippines	UF/MREC
Compacta	<i>Dieffenbachia maculata</i> (Lodd.) G. Don.	NA	Unknown	UF/MREC
64706	<i>Spathiphyllum</i> ×	NA	Unknown	UF/MREC

^zUniv. of Florida, Mid-Florida Research and Education Center, Apopka.

^yTwyford International, Inc. Apopka, Fla.

^xAgri-Starts II, Inc. Apopka, Fla.

^wUniv. of California–Riverside Botanic Garden, Riverside, Calif.

^vNot applicable as they are other aroids as controls.

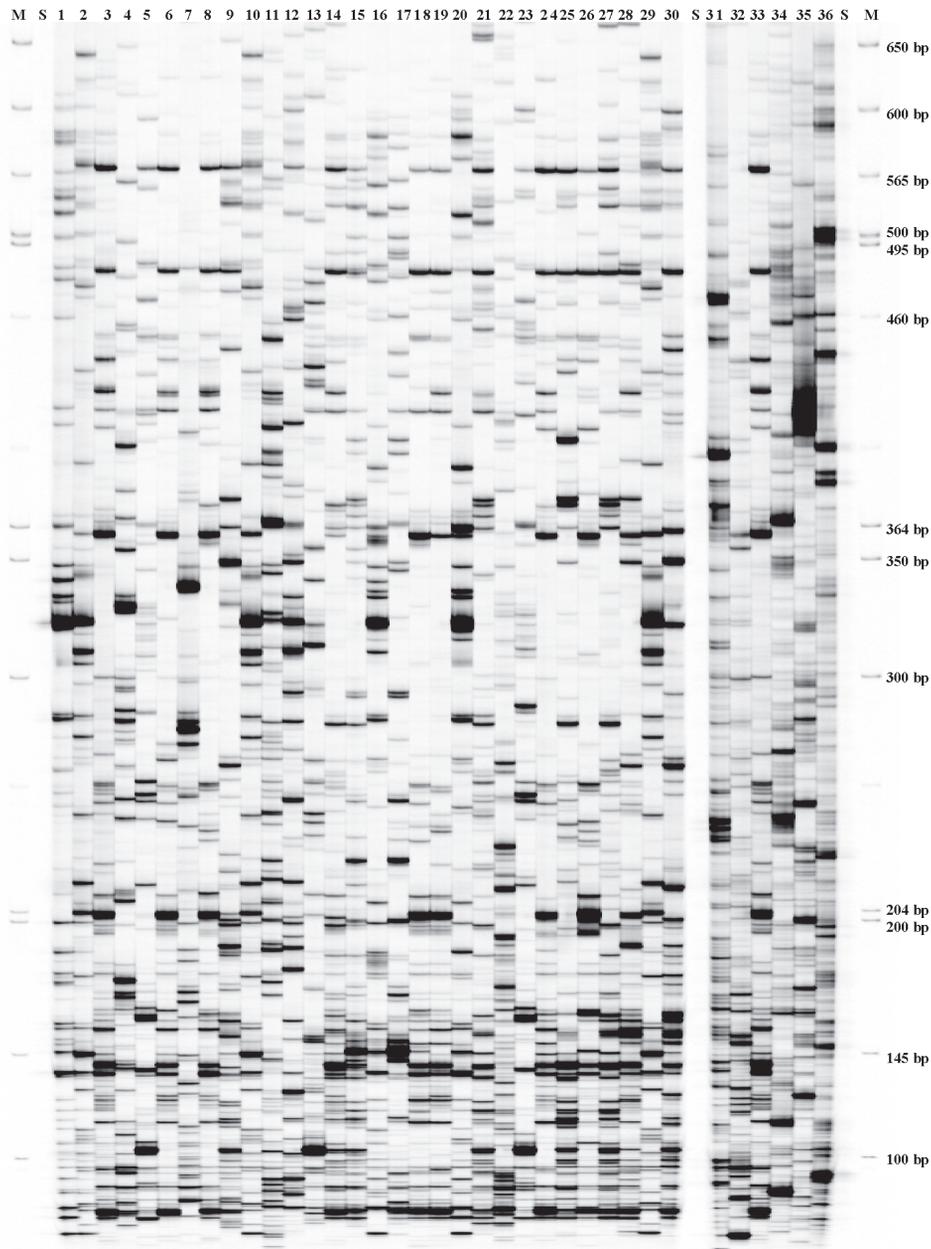


Fig. 1. Fluorescent-AFLP profiles of 30 *Philodendron* cultivars, one duplicated 'Moonlight' control, and five other aroid genera controls using primer IRD700 E+GG/M+CAA. The samples are arranged from left to the right in the order of (M) size markers, (S) space, (1) 'Selloum', (2) 'Xanadu', (3) 'Moonlight', (4) 'Scandent', (5) 'Angus ectifolium', (6) 'Autumn', (7) 'Banda Birdnest Philly', (8) 'Bituec', (9) 'Burke Marx', (10) 'Classic Xanadu', (11) 'Ginny', (12) 'Goeldii', (13) 'Greg Hambeli Square Petiole', (14) 'Greg Hambeli #1', (15) 'Greg Hambeli #2', (16) 'Hope', (17) 'Hybrid Selloum', (18) 'Imperial Green', (19) 'Imperial Red', (20) 'Octopus', (21) 'Panda', (22) 'Pertusum', (23) 'Pinnatifidum', (24) 'Prince of Orange', (25) 'Red Bristle', (26) 'Royal Queen', (27) 'Rudolph', (28) 'Sawtooth', (29) 'Showboat', (30) 'Tahiti Green', (S) space, (31) *Anthurium* control 'Red Hot', (32) *Spathiphyllum* control '64760', (33) *Philodendron* control 'Moonlight', (34) *Dieffenbachia* control 'Compacta', (35) *Alocasia* control 'Amazonica', (36) *Aglaonema* control 'Treubii', (S) space, and (M) size markers.

Table 2. AFLP primer combinations, primer sequences, total number of fragments generated by each primer set, number of polymorphic fragments detected, and percentages of polymorphic fragments used in the study of *Philodendron* cultivars.

Primer	Total no. of fragments	No. of polymorphic fragments	Polymorphic fragments (%)
IRD700 E+TC/M+CAA	106	70	60.0
IRD800 E+AA/M+CAA	96	68	70.8
IRD700 E+TC/M+CAT	106	68	64.2
IRD800 E+AA/M+CAT	130	75	57.7
IRD700 E+GG/M+CAA	110	72	65.5
IRD800 E+CC/M+CAA	116	71	61.2
Total	664	424	63.9
Average	110.7	70.7	63.9

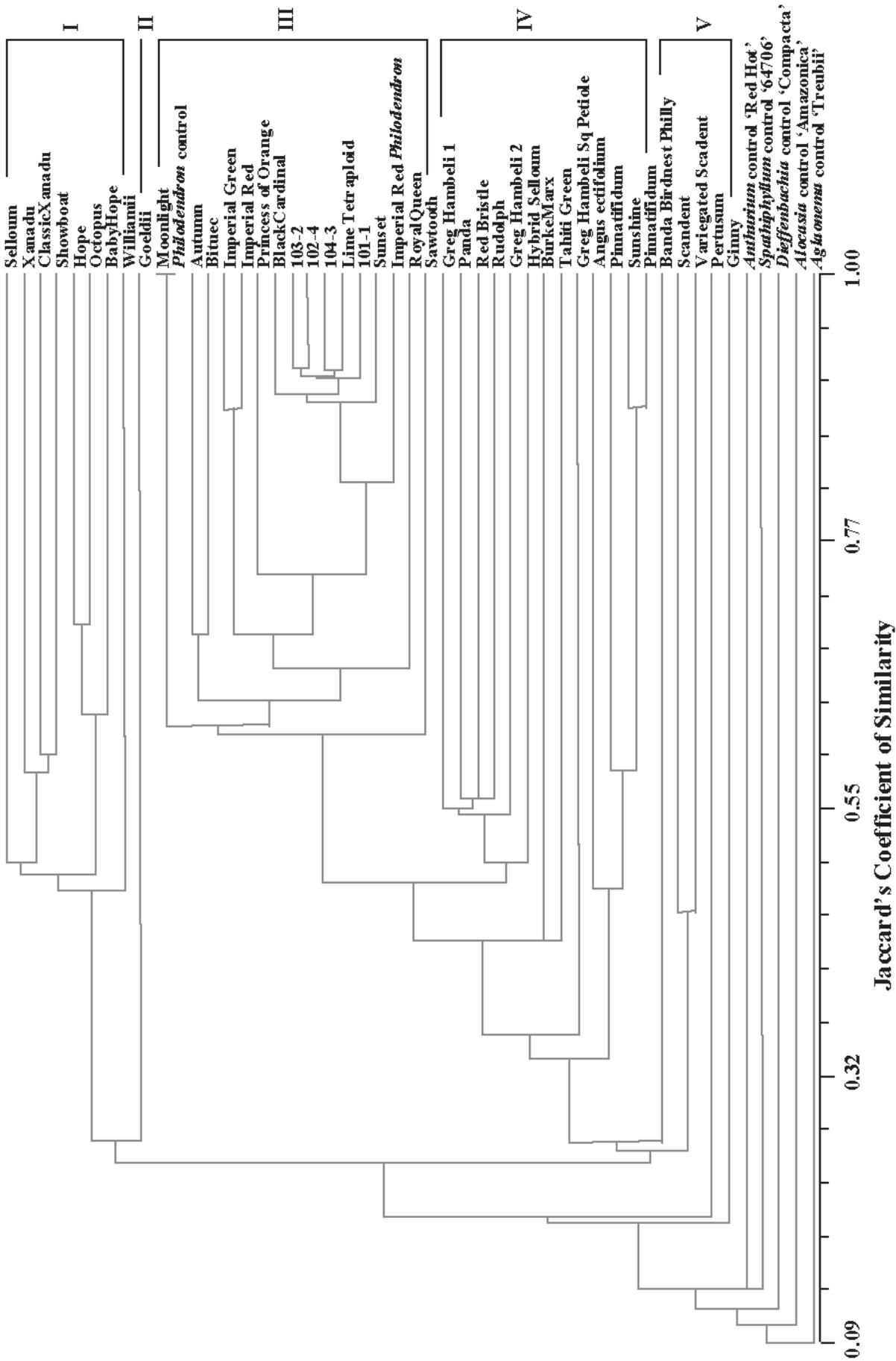


Fig. 2. Dendrogram of 43 *Philodendron* cultivars, a duplicate 'Moonlight', and five cultivars from other aroid genera resulted from the unweighted pair-group method of the arithmetic average (UPGMA) cluster analysis based on Jaccard's similarity coefficients obtained from 664-AFLP fragments.

for 'Williamsii', which belongs to *P. williamsii*. However, Jaccard's similarity coefficients among the *P. bipinnatifidum* cultivars ranged from 0.49 to 0.7, suggesting that *P. bipinnatifidum* might be rather heterozygous genetically. Similarly, 'Baby Hope', a somaclonal variant of 'Hope', shares a Jaccard's similarity coefficient of 0.63 with its parent 'Hope'. Jaccard's similarity coefficient between *P. bipinnatifidum* and *P. williamsii*, however, is only 0.48.

There is only one cultivar 'Goeldii' in cluster II. This cultivar belongs to *P. goeldii* G. Barroso, a species native to French Guyana and maybe other tropical American regions. 'Goeldii' is a unique appearing species whose stem is erect or hanging, sometimes tortuous (Mayo, 1991). Leaf blades are reniform in outline and pedately compound (Croat, 1997) or schefflera-shaped leaves on upright petioles growing from the center of the plant.

Cluster III contains 16 cultivars and most of them are self-heading hybrids developed by R.H. McColley at Bamboo Nursery in Apopka, Fla. 'Moonlight' is a hybrid with faintly yellow, ovate leaves. 'Autumn' has orange and bronze leaves in a rosette form. 'Bituec' may be related to 'Autumn'. Both 'Imperial Green' (U.S. plant patent No. 6,086) and 'Imperial Red' (U.S. plant patent No. 6,337) were selected by Paul DeCoster in Mello, Belgium, from seedlings of McColley's hybrids. During the 1960s, McColley made hundreds of crosses using more than 15 species as parents in all possible combinations and obtained 1,000,000 hybrid seeds (McColley and Miller, 1965). Not all hybrid seedlings were evaluated by McColley, and parental information or pedigrees of some commercial hybrids such as 'Moonlight', 'Autumn', 'Bituec', 'Imperial Green', and 'Imperial Red' were not documented. 'Prince of Orange' (U.S. plant patent No. 6,797) was selected from several crosses involving five parents: *P. domesticum* (stem climbing and with bright green leaves), *P. erubescens* (stem climbing and with purple to red leaves), *P. wendlandii* (stem erect), *P. imbe* Endl. (stem climbing and with purple to red leaves), and *P. canniifolium* Kunth (stem prostrate). 'Black Cardinal' is a hybrid developed from a series of crosses involved *P. wendlandii*, *P. domesticum*, *P. erubescens*, *P. imbe*, *P. fragrantissimum* (Hook) Kunth (stem climbing), and an unnamed species and was patented as U.S. plant patent No. 5,355. '103-2' was selected from a cross between 'Moonlight' and 'Prince of Orange'. '102-4' is a hybrid of 'Emerald Princess' and 'Moonlight'. The origin of '104-3' is unknown. 'Lime Tetraploid' is a tetraploidy Surath Vano. '101-1' is a hybrid selected from a cross between 'Prince of Orange' and 'Emerald Prince'. Parental information of 'Sunset' is not available. 'Imperial Red Philodendron', collected from the UCRBG, is apparently different from the 'Imperial Red' collected from Florida as their Jaccard's similarity coefficient is only 0.66. 'Royal Queen' is a hybrid with blood-red stem and petioles; medium-sized ovate leaves, bronze when young, and later glossy rich green. The origin of 'Sawtooth' is not documented.

There are 13 cultivars in cluster IV, and all have semi-vining growth style. The origin of 'Greg Hambeli 1' is unknown. 'Panda' is a *P. bipennifolium* Schott. (syn. *P. panduraeforme* Kunth) or called fiddleleaf philodendron or horsehead philodendron. This species is a sparsely branched semi climber and native to Southeastern Brazil (Huxley, 1994). 'Red Bristle' may be related to *P. pedatum* (Hook) Kunth (syn. *P. laciniatum* Engl.). It may originate from southern Venezuela to southeastern Brazil with a population in northern Colombia (Bown, 2000). Background information of 'Rudolph' is unknown. 'Greg Hambeli 2' may be a relative of 'Greg Hambeli 1'. Again, its origin is unclear. 'Hybrid Selloum' could be a mislabeled plant as its Jaccard's similarity coefficient with the 'Selloum' related cultivars in cluster I is only 0.25. Cultivar

Burke Marx has light green and ovate-oblong leaves. It may be a cultivar of *P. imbe*. The background information of 'Tahiti Green' is not available. Information regarding 'Greg Hambeli square petiole' is unknown. 'Angus Ectifolium' could actually be a *P. angustisectum* Engl., a moderate-sized semi climber. Leaves are ovate in outline but deeply pinnatifid looking like palm blades. This species is native to Colombia. There are two 'Pinnatifidum', one collected from central Florida and the other collected from the UCRBG. Both are *P. pinnatifidum* (Jacq.) Schott., a species originates from Brazil, but their Jaccard's similarity coefficient is only 0.58. The background of 'Sunshine' is unclear; its close association with the 'Pinnatifidum' may indicate that the two are closely related as the Jaccard's similarity coefficient between the two is 0.79.

Cluster V has five cultivars. The background of cultivar Banda Birdnest Philodendron is unknown. Both 'Scandent' and 'Variegated Scandent' are *P. scandens*, or commonly referred to as heartleaf philodendron. This species is native to Mexico, the West Indies, and southeastern Brazil. Heartleaf philodendron is a fast growing, slender climber with pendent terminal stems. It used to be the dominant plant in the foliage plant industry with its highest wholesale value of a single species from the 1950s to 1960s. Morphologically, the only difference between the two 'Scandent' cultivars is that one has solid green leaves and the other has variegated leaves. The solid green 'Scandent' cultivar has been cultivated for more than two centuries since its first introduction in 1793 (Bown, 2000). This plant is propagated through eye cutting because it has never produced seeds in cultivation and not been propagated by tissue culture. The variegated cultivar is a recent discovered sport from the solid green cultivar. However, their Jaccard's similarity coefficient is only 0.46; such distant relationship may suggest that somatic mutations could have been accumulated in 'Scandent'. 'Pertusum' is a *P. pertusum* Kunth & Bouche and it has been called split-leaf philodendron in the foliage plant industry. However, this plant may actually be a *Monstera deliciosa* Liebm., another genus of the family Araceae, as its Jaccard's similarity with other philodendrons is only 0.2 or lower. 'Ginny' is a cultivar located in cluster V with split leaves as well. It may, like 'Pertusum', not belong to *Philodendron* since its Jaccard's similarity coefficient is only 0.19 or less comparing with other *Philodendron* cultivars.

We included five other genera of Araceae (*Aglaonema*, *Anthurium*, *Alocasia*, *Dieffenbachia*, and *Spathiphyllum*) in this study. These five generic accessions were properly positioned outside the *Philodendron* clusters and the genetic similarities among these five genera are ≤ 0.14 . They shared a genetic similarity of no higher than 0.10 with any *Philodendron* samples.

FIVE GROUPS OF CULTIVATED PHILODENDRONS AND THEIR IMPLICATIONS WITH BREEDING. The PCA clearly separated the 43 *Philodendron* cultivars into five clusters (Fig. 3). If one thinks that the UPGMA analysis reflected in the dendrogram (Fig. 2) only loosely clustered cultivars in clusters IV and V, the PCA confirms the classification of the cultivated philodendrons into five groups. Cultivars in the cluster I are all arborescent types. 'Goeldii' is the only cultivar in cluster II, which has erect or hanging, sometimes tortuous stem and schefflera-shaped leaves. Cultivars in cluster III are all selfing-heading and predominantly derived from McColley's breeding program. Semi-vining cultivars are positioned in cluster IV, and the true vining type is situated in cluster V. The true vining type of philodendrons in cluster V are genetically distant from other philodendrons and relatively closer to other aroid genera (Figs. 2 and 3). Comparing to the traditional

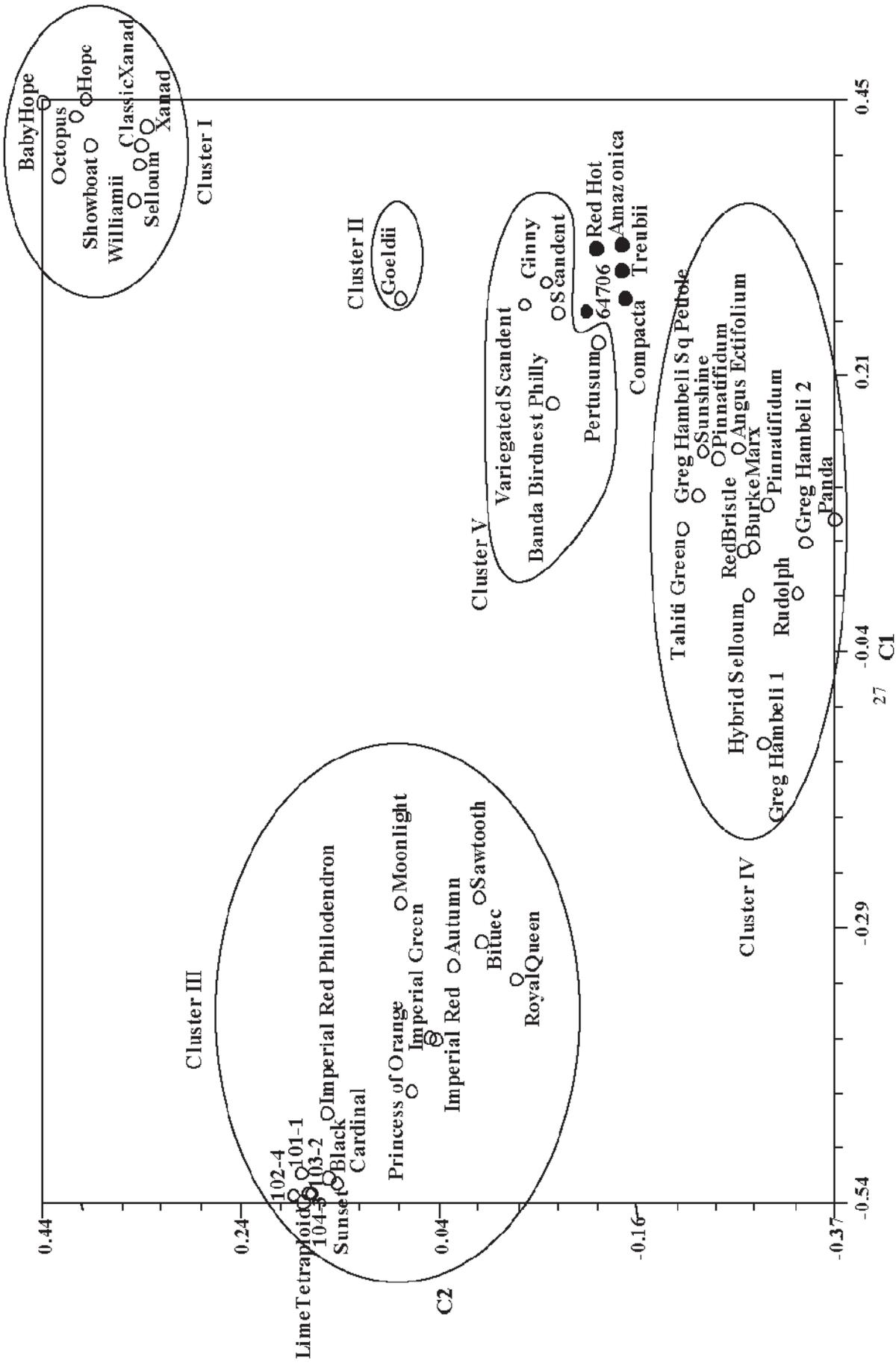


Fig. 3. Scatter diagram of first two principal coordinates (PC1 and PC2) from principal coordinated analysis of 43 *Philodendron*, a duplicate 'Moonlight', and five cultivars from other aroid genera based on 664 AFLP fragments.

Literature Cited

- three groups, it appears that McColley and Miller (1965) did not take 'Goeldii' and semi-vining type into their considerations. Our study showed that semi-vining type should be an independent group, which is based on the following considerations: 1) semi-vining plants were genetically distant from the true vining types (Jaccard's similarity of 0.26); 2) this group of plants has large lanceolate blades, varying in leaf colors and thickness, and strong stems; and, most importantly, 3) semi-vining plants were primary materials used for crossing with self-heading species such as *P. wendlandii* by which interspecific hybrids with various colors were produced. Therefore, we postulate that some species from the semi-vining group may actually be bridge species that can be used to cross with either arborescent or even some true vining type to create new interspecific hybrids.
- Additionally, since philodendrons are open-pollinated and propagated mainly by vegetative means, some species may be extremely heterozygous. For example, 'Hope', selected from selfing of 'Selloum', shares a Jaccard's similarity coefficient of only 0.5 with its parent. Such large genetic difference may suggest that new cultivars can be directly developed through selfing of highly heterozygous parents. Additionally, 'Baby Hope' was selected from somaclonal variants of 'Hope', Jaccard's similarity coefficient between the two is 0.62. Sport of 'Variegated Scanden' shares a Jaccard's coefficient of 0.46 with its parent 'Scanden'. These rather distant relationships between somaclonal variants or sport with their parents indicate that new cultivars can also be developed from selection of somaclonal variants or sports of philodendrons.
- Furthermore, this study reveals that cultivars with the same names are genetically different. For example, 'Pinnatifidum' collected from central Florida has a Jaccard similarity coefficient of 0.58 with the same named cultivar collected from UCRBG. It might be possible that both belong to *P. pinnatifidum* but are different cultivars. 'Imperial Red' cultivated in central Florida share a Jaccard's coefficient of 0.66 with 'Imperial Red Philodendron' collected from UCRBG. These two cultivars might come from R.H. McColley's breeding program as they are morphologically similar. Apart from different cultivars being given the same names, mislabeling cultivars also occurs. 'Hybrid Selloum' resembles little with *P. bipinnatifidum* 'Selloum' both morphologically and genetically. The mislabel could be a problem that affect philodendron germplasm conservation and utilization as valuable genetic resources could be lost due to the mislabeled same names. Molecular marker technologies, such as AFLP, show great promise for cultivar identifications.
- Using the AFLP technique, we were able to position 43 *Philodendron* cultivars into five clusters based on the polymorphism generated by six AFLP primer sets as well as their growth habits. We propose the five clusters are five groups (arborescent, goeldii, self-heading, semi-vining, and vining types) of cultivated ornamental foliage philodendrons. Plants from the semi-vining type may be able to cross with species in the other groups to create new interspecific hybrids. Additionally, the AFLP analysis suggests that 'Pertusum' and 'Ginny' may not belong to the genus *Philodendron*. Nevertheless, the AFLP profiles and the clusters identified from this study can be used as reference for future interspecific hybrid development. The genetic similarity among cultivars established could help in *Philodendron* germplasm identification, preservation, and new cultivar development.
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