The Foliage Plant Industry

Chapter · June 2010

DOI: 10.1002/9780470650882.ch2

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Cultivar Development of Ornamental Foliage Plants*

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*The authors thank Dr. Adelheid R. Kuehnle at the University of Hawaii for providing published and unpublished information used in this review. They also thank Terri Mellich, Edmund Thralls, and Kelly Everitt for critically reading and editing the manuscript. This research was supported by the Florida Agricultural Experiment Station and approved for publication as Journal Series No. R-09116.

Plant Breeding Reviews, Volume 23, Edited by Jules Janick
ISBN 0-471-35421-X

I. INTRODUCTION

Defined literally, foliage plants would include all plants grown for their attractive leaves rather than flowers or fruits. In general horticultural terms, however, foliage plants are those with attractive foliage and/or flowers that are produced in containers in shaded greenhouses and used primarily as living specimens for interior decoration or interiorscaping (Chen et al. 2002). In common terminology, foliage plants are referred to as houseplants. Foliage plants in the tropics, however, may also grow under shade as landscape plants.

Currently, more than 500 species with various forms, colors, textures, and styles are grown as foliage plants. The majority of them are indige-

nous to either the tropics or subtropics. The tropics have warm and stable temperatures, an abundant water supply, 12-hour daylength, and a continuous growing season. Tropical foliage plants grow under the tree canopy on the shaded forest floor or grow as lianas (climbing vines) or even live in trees as epiphytes. Characteristics of such foliage plants include their tolerance of low light, sensitivity to chilling temperatures, day neutral photoperiod response, and lack of dormancy. In the subtropics, summer is hot and humid but winter may have frost. Foliage plants originating from this climate are more adaptable to heat, drought, and chilling temperatures and may also show winter dormancy. Desert plants such as succulents and cacti have unique foliage, styles, and shapes that have been evolved for coping with heat and drought stresses. Few foliage plants are native to the temperate climate. English ivy (*Hedera helix*) is probably the most significant one whose juvenile form has been widely used as either potted or hanging-basket foliage plants.

The use of plants indoors began at least 3,500 years ago when the Sumerians and ancient Egyptians started growing small trees in containers. The ancient Chinese expanded the variety of plants used for indoor decoration (Chase 1997). Wealthy merchants of Florence, Genoa, and Venice introduced plants from the East into Europe in the fifteenth century. Plant collectors in Holland and Belgium also imported plants from Asia Minor and the East Indies starting at the time of the Crusades. A desire for exotic plants developed among the aristocracy of France and England by the middle of the sixteenth century. Many wealthy persons of Europe constructed orangeries and conservatories in the seventeenth century. By the following century, an estimated 5,000 species of exotic plants had been brought into Europe (Smith and Scarborough 1981). In the second half of the nineteenth century, foliage plants were gaining popularity in Europe. The grand drawing rooms of Victorian houses had their fill of palms and ferns (Lowe 1861).

In the late 1890s, foliage plants from conservatories, botanical gardens, and private estates were generally brought into commercial production, and these plants were sold for use in middle- and upper-class households. At the same period, shiploads of foliage plants from Europe were sold to greenhouse growers in the Northeast United States for continued growth or subsequent resale. In less than two decades, the production of foliage plants moved to California and Florida because of favorable climatic conditions. The Californian industry began with Kentia palm (*Howea forsteriana*) and pothos (*Epipremnum aureum*) in the 1920s, and later heartleaf vine (*Philodendron scandens oxycardium*) and Norfolk Island pine (*Araucaria bidwilli*) in the 1940s (Smith and Scarborough 1981). Florida growers have cultivated Boston fern (*Nephrolepis exaltata*) since 1912. Heartleaf vine was introduced to Florida in 1928 and

Chinese evergreen (*Aglaonema modestum*) and rubber plant (*Ficus elastica*) in the 1930s (Smith and Scarborough 1981). Florida is now the leading state in the production of foliage plants, accounting for more than 55% of the national wholesale value since the 1960s.

The steady increase in foliage plant production has been attributed in part to the back-to-earth, back-to-nature movement of the 1970s and continues unabated (Manaker 1997). The wholesale value of foliage plants in the United States rose from $29 million in 1969 to $585 million in 2001 (USDA 2002). Foliage plants enhance the interior environment and fulfill a psychological need by bringing beauty and comfort to our surroundings (Manaker 1997). Furthermore, foliage plants have been shown to be capable of purifying indoor air and have been demonstrated to remove 87% of pollutants such as formaldehyde and benzene from sealed chambers within 24 hours (Wolverton 1989). The beautification of interior environments and purification of indoor air have become key elements in promoting the use of foliage plants.

Another important factor in the steady growth of the foliage plant industry is the continued introduction of new plants and development of new cultivars that dramatically expand options for foliage plant usage in interiorscaping (Chen et al. 2002). The aim of this chapter is to review several aspects relating to the development of foliage cultivars, including plant acquisition and introduction, selection of mutations, and interspecific hybridization. Four popular groups (aroids, bromeliads, ferns, and palms) are emphasized along with four other popular genera. Because much research is carried out by private companies, documentation in the scientific literature is uneven and, therefore, anecdotal information is included.

II. ORIGIN OF NEW CULTIVARS

There are three main avenues for new foliage plant cultivars to enter the commercial trade: (1) plant acquisition and introduction, (2) selection of natural and induced mutations from established cultivars, and (3) hybridization and progeny selection.

A. Plant Acquisition and Introduction

Plant acquisition and introduction played important roles in the initial development of the foliage plant industry in the United States and will continue to be important in introducing new species and improving existing cultivars by providing germplasm for breeding. Until recently, neither the U.S. National Plant Germplasm System (NPGS) nor the Inter-

national Board for Plant Genetic Resources (IBPGR) had been involved in conservation of foliage plant germplasm. The Ornamental Plant Germplasm Center (OPGC), established in 1999 at the Ohio State University, is considering conserving only five aroid genera (*Aglaonema*, *Anthurium*, *Dieffenbachia*, *Philodendron*, and *Spathiphyllum*) at this time. Most foliage plant resources have been collected and maintained by private plant collectors or public institutions such as botanical gardens or conservatories.

1. Plant Acquisition. There are two avenues of obtaining new foliage germplasm: direct collection from the wild (usually done in conjunction with knowledgeable botanical garden personnel or avid private collectors) or acquisition of established material from botanic gardens or private collectors. Dr. Thomas B. Croat, one of the world's leading experts on Araceae, spends months each year in the tropics as part of his work at the Missouri Botanical Garden in St. Louis. He has collected more than 10,000 living specimens and maintains the world's largest and most comprehensive collection of living aroid plants in the Garden's greenhouses. Croat's work resulted in the revision of *Anthurium*, *Dieffenbachia*, and *Syngonium* (Croat 1982, 1983, 1986, 1997). Dr. Frank B. Brown of Valkaria Tropical Garden, Valkaria, Florida, made more than 50 explorations in the jungles of southeast Asia and brought valuable materials of *Aglaonema* (Brown 2001) to Florida. *Calathea* owes much of its popularity to collections from Central America (Kennedy 1973). Not all acquisitions involve jungle exploration. For example, *Ficus elastica* 'Decora' was introduced to Florida from a plant collected during a visit to Holland in 1954 (Griffith 1998a).

Collected materials are often exchanged among members within individual plant societies such as the American Ivy Society, Bromeliad Society, and International Aroid Society, all based in Florida. Plant materials are also generously shared between private collectors and public institutions such as botanical gardens and universities. For example, foliage plant breeding programs at the University of Florida and University of Hawaii have received great benefit from valuable germplasm resources provided by both private collectors and botanical gardens, particularly the Missouri Botanical Gardens. However, maintaining tender tropical plants in greenhouses is expensive, and it is conceivable that changes in funding or individual research interests could result in a loss of plant diversity in these invaluable collections.

2. Evaluation and Utilization of New Introductions. Most newly collected foliage plants need to be systematically evaluated. This process may be an individual or joint effort between collectors, growers, and/or

researchers. Evaluation of a newly collected plant prior to release includes taxonomic identification, methods of propagation, cultivation, and assessment of ornamental value. For example, an exotic plant with wide ovate-lanceolate leaves and orange-colored petioles was collected from Thailand and named *Palisota* by the collector. A later study by taxonomists determined it to be *Chlorophytum orchidantheroids*. Although this plant bears seeds, a local tissue culture firm successfully propagated it through tissue culture and provided a large number of liners for evaluation at the University of Florida. The plant was evaluated based on form, color, and style, as well as performance under interior conditions and was shown to be well adapted to a low light intensity of 8 μmol m^{-2} s^{-1} (Chen et al. unpublished). This unique plant was later named *C. orchidantheroids* 'Fire Flash' and is now produced as a new foliage plant.

B. Mutations from Vegetative Propagation

1. Sport Selection. Mutant clones or sports have been widely used in foliage plant production as a source of new cultivars. Since most foliage plants are propagated vegetatively, spontaneous mutations may accumulate throughout consecutive generations, and offshoots or cuttings generated from the mutated cells may develop into mutant clones. In the literature, spontaneous somatic mutations are often called bud mutations, bud sports, or sports (van Harten 1998). These mutations may be either nuclear or cytoplasmic in origin and may affect an entire bud or other plant organ or only part of an organ, as in the case of chimeras or mosaics (Neilson-Jones 1969; Marcotrigiano 1997). The causes of somatic mutation could be the result of transposon activities, changes in chromosome number, or loss of genes (Pratt 1983; van Harten 1998). Somatic mutations are as common as or more common than germ-cell mutations at rates of 10^{-3} to 10^{-5} per locus per generation (Harrison and Fincham 1964; Simmonds 1979).

Success in sport selection depends on the availability of highly variable stock plants and the quantity of propagules produced from the stock plants. For example, heartleaf philodendron (*Philodendron scandens oxycardium*) used to be the most commonly grown foliage plant in Florida from the 1950s to 1960s; millions of cuttings were produced each year. However, no single mutant was selected from the cuttings because this plant is genetically stable. On the other hand, English ivy (*Hedera helix*), another cutting propagated foliage plant, has more than 200 cultivars released; all of them were selected from sports (Rose 1996). Another factor that affects the success of a selected sport is its relative

stability in commercial production. Unstable sports are discarded if they fail to maintain anticipated phenotypes over time.

2. Somaclonal Variant Selection. In addition to sports commonly observed in those traditional vegetatively propagated foliage plants, another form of somatic variation or genetic instability occurs in tissue culture and has been termed somaclonal variation (Larkin and Scowcroft 1981). Compared to spontaneous somatic mutations, somaclonal variations usually occur at much higher frequencies (Buiatti and Gimelli 1993). The increased frequencies have been attributed to (a) pre-existing genetic variation in explant tissues, (b) genetic variation induced by mutagenic action of chemical compounds in the culture media, and (c) variation as a response of the plant genome to stress, including DNA methylation, gene amplication, and activities of transposons (Novak 1991).

Since many foliage plants are propagated by tissue culture, selection of variants for desired phenotypes has become an important method of new cultivar development. *Syngonium* provides an excellent example of somaclonal variant selection as a cultivar development tool. The *Syngonium* pedigree in Fig. 6.1 shows how 22 cultivars, all somaclonal variants, were selected from large populations of tissue cultured material grown in commercial greenhouses. All 22 cultivars can be traced back to the original 'White Butterfly' clone. Each variant selected was micropropagated and each remained stable enough to become a named cultivar. Subsequent mutations resulted in additional cultivars. Several

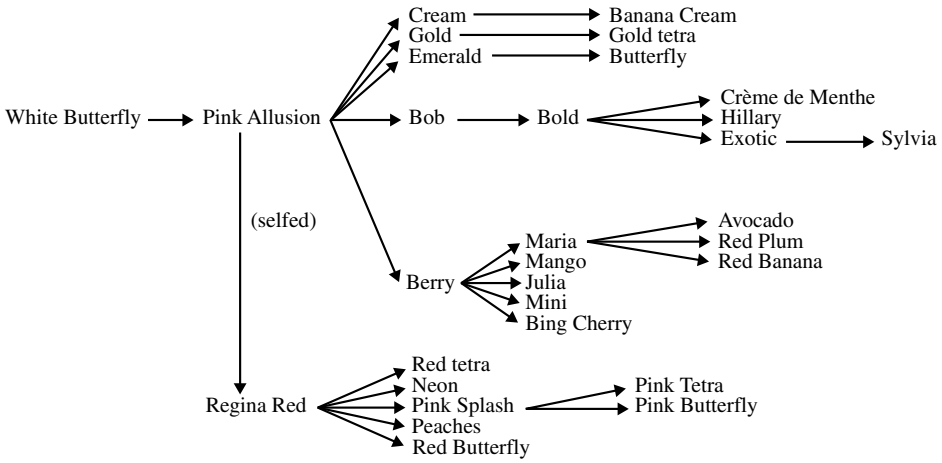

Fig. 6.1. Pedigree of somaclonal mutant *Syngonium* cultivars from tissue culture that have become commercialized. All cultivars can be traced back to 'White Butterfly'.

of the cultivars have pink or reddish coloration in the foliage, which was not evident in 'White Butterfly'. The first mutant, named 'Pink Allusion', was self-pollinated to generate a population that yielded a selection named 'Regina Red'. When placed into tissue culture, 'Regina Red' produced five somaclonal variants of which 'Pink Splash' yielded 'Pink Tetra' and 'Pink Butterfly' (Fig. 6.1). This series of mutations also established that the pink trait evident in the original 'Pink Allusion' was genetically stable and could be transmitted through seed.

Anthurium somaclonal variants in the Mid-Florida Research and Education Center (MREC) at the University of Florida include 'Orange Hot' (a purple-colored form has also been found and is under evaluation) from *A.* 'Red Hot'. 'Diamond Bay' and 'Emerald Bay', two somaclonal variants of *Aglaonema*, were introduced in 2002 by MREC (Henny et al. 2003a). Many *Dieffenbachia* cultivars were also released from a selection of somaclonal variants from tissue-cultured populations. For example, *Dieffenbachia* 'Tiki' is a sport derived from *D.* 'Memoria Corsii', and 'Snow Flake', a new cultivar in the market, was derived from 'Tiki'.

Selected somaclonal variants, however, if unstable, could be detrimental to a cultivar because nonuniformity in crops becomes a costly liability to the clonal propagator. This was the case for *Dieffenbachia* hybrids 'Starry Nights' (Henny et al. 1989) and 'Star White' (Henny et al. 1992b), which were too unstable in tissue culture to be successful commercially.

C. Hybridization

Foliage plants are predominantly cross-pollinating species. Parents used in foliage plant hybridization are not usually derived from inbred, single-seed descent, or pedigree selection, because inbreeding depression limits development of inbred lines in most foliage plant genera. Traditional breeding through hybridization has focused on maximizing heterozygosity. By intercrossing distinct clones, both of which have desirable characters, populations are created that may be utilized directly for selection of new clones. If the parent clones are heterozygous, each seedling is a potential new cultivar that can be fixed by vegetative propagation.

Interspecific hybridization is the most common practice in producing hybrid cultivars in foliage plant breeding. Interspecific hybridization offers opportunities for obtaining gene recombinations not possible with intraspecific hybridization and expands the range of genetic variability beyond that of a single species. Additionally, interspecific hybridization may create hybrids with unique ornamental characteristics by making

genetic combinations that could not be achieved through intraspecific hybridization. Interspecific hybrids in genera of aroids and bromeliads are discussed in Section V.

With the advance of tissue culture, haploid plants can be produced through culture of excised anthers/pollen or ovaries/ovules. By doubling chromosome number, homozygous diploid plants can be procured in a single generation. The fertile homozygous plants can be used for producing inbred lines required to utilize hybrid vigor. Eeckhaut et al. (2001) initiated *Spathiphyllum* haploid production using in vitro ovary culture. Two doubled haploid genotypes, verified with flow cytometry and AFLP-patterns, were obtained from the cultivar 'Stefanie' (Eeckhaut et al. 2001). Such research is critical to develop true breeding parental lines that can be used to exploit heterosis of *Spathiphyllum*.

D. Transgene Technology

Transgene technology has been proven to be a powerful method of altering crop characteristics (Hansen and Wright 1999) and should be particularly useful in foliage plant improvement. Foliage plants are not edible and are valued by their esthetic appearance. Transgenic foliage plants would not cause genetic contamination of other crops because most are vegetatively propagated. However, application of transgene technology in foliage plants is quite limited. *Anthurium* is probably the only foliage plant being successfully transformed thus far (see details in Section VI).

E. Plant Patents

A total of 416 United States Plant Patents have been issued to 18 genera/groups of foliage plants since 1976 (Table 6.1). Among them, 66 patents were issued from 1976 through 1989 and 243 patents were issued in the 1990s. Current foliage plant patent activity appears to be increasing because 107 patents have been issued between January 2000 to August 2002.

The bromeliad group, encompassing five genera (*Aechmea*, *Cryptanthus*, *Guzmania*, *Neoregelia*, and *Viresea*), was the most active, with 107 patents issued. *Anthurium* followed with 98, including several for cutflower cultivars. *Spathiphyllum*, *Aglaonema*, *Dieffenbachia*, *Ficus*, and *Philodendron* followed with 55, 35, 31, 25, and 16 patents, respectively.

All 416 patents were reviewed to determine the method by which the cultivars were generated. Breeding analysis could be classified into four groups: (1) hybridization, (2) selection of naturally occurring sports,

Table 6.1. A summary of all U.S. Plant Patents issued to 18 genera/groups of ornamental foliage plants from 1976 through August 10, 2002.

Genus/Group	1976–1979	1980–1989	1990–1999	2000–2002	Total
Aglaonema	0	2	29	4	35
Alocasia	0	0	0	0	0
Anthurium	2	3	59	34	98
Bromeliad[z]	0	3	68	36	107
Calathea	0	0	7	1	8
Chlorophytum	0	0	0	0	0
Cordyline	0	0	2	0	2
Dieffenbachia	1	14	13	3	31
Dracaena	1	3	1	7	12
Epipremnum	0	0	0	0	0
Fern[y]	3	2	4	1	10
Ficus	2	3	17	3	25
Hedera	0	1	0	0	1
Palm[x]	0	0	0	0	0
Philodendron	1	11	1	3	16
Shefflera	1	2	3	2	8
Spathiphyllum	0	7	36	12	55
Syngonium	0	4	3	1	8
Totals	11	55	243	107	416

[z]Bromeliad included 5 genera (*Aechmea*, *Cryptanthus*, *Guzmania*, *Neoregelia*, and *Viresea*).

[y]Fern included 7 genera (*Adiantum*, *Asplenium*, *Cyrtomium*, *Davallia*, *Nephrolepis*, *Platycerium*, and *Pteris*).

[x]Palm included 5 genera (*Chamaedorea*, *Chrysalidocarpus*, *Howea*, *Phoenix*, and *Rhapis*).

(3) selection of somaclonal variants from tissue culture, or (4) selection of mutants induced from irradiated material.

Hybridization was the most prevalent activity, with 289 of 416 (69%) patents resulting from crossing and selection (Table 6.2). *Anthurium* had the highest number of patented hybrids, with 92 of 98 (94%) derived from traditional breeding; bromeliads had 82, followed by *Spathiphyllum* (47), *Aglaonema* (32), *Dieffenbachia* (20), and *Philodendron* (14). Even with the obvious overall importance of hybridization, only seven genera/groups produced patented hybrids, while eleven genera/groups indicated no hybridization activity. There were 112 (27%) naturally occurring foliage plant sports patented: *Ficus* and bromeliads each showed 23 patents originating from sports, followed by *Dracaena* with 12, *Dieffenbachia* with 11, and *Hedera* with one. *Alocasia*, *Chlorophytum*, *Epipremnum*, and palms did not have patented sports. Tissue culture resulted in 12 patented foliage plants, including 4 *Calathea*, 2

Table 6.2. A listing of the sources of all U.S. Plant Patents issued to 18 genera/groups of ornamental foliage plants from 1976 through August 10, 2002. Sources include selections from hybrid populations, naturally occurring sports, variants from tissue culture produced populations, and irradiation induced mutation.

Genus/Group	Total issued	Hybrids	Sports	Tissue culture variants	Irradiation
Aglaonema	35	32	2	1	0
Alocasia	0	0	0	0	0
Anthurium	98	92	4	2	0
Bromeliad[z]	107	82	23	2	0
Calathea	8	0	4	4	0
Chlorophytum	0	0	0	0	0
Cordyline	2	0	2	0	0
Dieffenbachia	31	20	11	0	0
Dracaena	12	0	12	0	0
Epipremnum	0	0	0	0	0
Fern[y]	10	0	9	1	0
Ficus	25	0	23	0	2
Hedera	1	0	1	0	0
Palm[x]	0	0	0	0	0
Philodendron	16	14	1	1	0
Shefflera	8	0	8	0	0
Spathiphyllum	55	47	8	0	0
Syngonium	8	2	4	1	1
Totals	416	289	112	12	3

[z]Bromeliad included 5 genera (*Aechmea*, *Cryptanthus*, *Guzmania*, *Neoregelia*, and *Viresea*).

[y]Fern included 7 genera (*Adiantum*, *Asplenium*, *Cyrtomium*, *Davallia*, *Nephrolepis*, *Platycerium*, and *Pteris*).

[x]Palm included 5 genera (*Chamaedorea*, *Chrysalidocarpus*, *Howea*, *Phoenix*, and *Rhapis*).

Anthurium, 2 Bromeliads, and one each of *Aglaonema*, fern, *Philodendron*, and *Syngonium*. Finally, 3 patents resulted from irradiation-induced mutants (2 *Ficus* and 1 *Syngonium*). Aroids (207 of 289 = 72%) and bromeliads (82 of 289 = 28%) accounted for 100% of foliage plant patents that involved hybridization.

III. BREEDING TECHNIQUES

A. Control of Flowering

Careful planning is required to ensure a sufficient supply of flowers for foliage plant breeding, especially in families as diverse as members of the Araceae and Bromeliaceae. Genera such as *Aglaonema* and *Dieffenbachia*,

both aroids, naturally produce only 3–4 inflorescences per stem per year, and different species within each genus may not flower simultaneously (Henny 2000). This potential barrier to breeding has been overcome by the use of gibberellic acid (GA_3) sprays to stimulate flowering of aroid genera, including *Aglaonema*, *Caladium*, *Calathea*, *Dieffenbachia*, *Spathiphyllum*, *Syngonium* (Henny 1995), and *Philodendron* (Chen et al. 2003). GA_3 has also been used to stimulate flowering of *Cordyline* (Fisher 1980). Treatment generally consists of a single foliar spray of 250 to 1,000 ppm GA_3. GA_3 treatment also increases the number of flowers per plant, and, in most cases, induces different species of the same genus to flower simultaneously (Henny 1995).

Bromeliads can be induced to flower by treating them with compounds that emit ethylene such as ethephon (chloroethane phosphoric acid). Crops can be sprayed at different times of the year to ensure salable plants in spike or in color at desired seasons or to produce flowers for breeding. Ethylene compounds can be applied at the rate of approximately 2,500 ppm. Treated plants should flower about two months after treatment (Griffith 1998b).

B. Pollination Methods

1. Genera with Unisexual Flowers. *Aglaonema*, *Dieffenbachia*, *Epipremnum*, *Philodendron*, and other aroids possess unisexual flowers that are held on a common structure termed the spadix. Pistillate flowers on the same spadix mature simultaneously, as do staminate flowers. However, inflorescences exhibit protogyny in that pistillate flowers (located on the lower half of the spadix) are receptive before staminate flowers produce pollen (Henny 2000). This dichogamous nature discourages self-pollination and promotes outcrossing. It is necessary to obtain pollen from a separate inflorescence and to manually transfer it to the inflorescence selected as the seed parent. This can be done with a small, soft brush by brushing the pollen into a container. Alternatively, the entire inflorescence may be removed and turned so the spathe is on the bottom and catches any pollen that becomes dislodged from the spadix. Pollination can be performed via the same brush used to collect the pollen. First make the brush sticky by gently brushing it against the stigmatic surfaces, then dip it into the pollen supply, and lightly brush the pollen on the stigmatic surfaces of receptive flowers (Henny 2000).

Receptivity of female flowers coincides with unfurling of the spathe. In some *Philodendron* species, the entire inflorescence becomes warm to the touch as an indicator of receptivity (Chen et al. 2003; McColley and Miller 1965). Receptivity of *Aglaonema* and *Dieffenbachia* flowers

lasts at least 24 hours, as evidenced by pollen germination studies (Henny 1988). Spathes from these two genera normally begin to unfurl at night and pollination can occur anytime the following day. Seed has been obtained from flowers of both genera pollinated one day after spathe unfurling, but the number of seeds is small. Female flower surfaces that have become discolored and mushy are no longer receptive.

Following pollination, *Dieffenbachia* flowers require 100% relative humidity for pollen to germinate (Henny 1980). This can be done by wrapping the entire spadix with moistened paper toweling and enclosing it in a plastic bag. The wrap is removed the next day so that it does not interfere with pollen production. Pollen germination in *Aglaonema* is greater when provided high humidity (Henny 1985) but is not as sensitive as *Dieffenbachia*. There are no reports that *Philodendron* require high humidity for seed set.

Palms (*Chamaedorea* and *Rhapis*) have relatively large flowers that are easy to manipulate, but the majority produces unisexual flowers and only a few species have bisexual flowers (Wilfret and Sheehan 1981). Species with unisexual flowers are generally monoecious, but a few are dioecious. The sequence of floral opening and inflorescence type must be observed to determine when pollen is shed and when stigmatic surfaces are receptive. Details of palm pollination were documented by Henderson (1986).

2. Genera with Bisexual Flowers. Aroid genera with bisexual flowers include *Anthurium* and *Spathiphyllum*; unfurling of the spathe reveals many uniform flowers located along the entire spadix. All flowers on a *Spathiphyllum* spadix mature simultaneously. In *Anthurium*, new flowers become receptive each day, beginning at the spadix base and advancing gradually toward the top over a two-week period. Pistillate flower receptivity is indicated by a glistening shine of stigmatic surfaces and stickiness to the touch. It is sometimes accompanied by small drops of exudate. Flowers may remain receptive for more than a day, so timing of pollination is not as critical (Henny 2000).

The stigmatic surfaces of both *Anthurium* and *Spathiphyllum* become dry and brown before pollen is dehisced; therefore, emasculation is not required. Pollen begins to appear along the spadix, usually at the bottom first and proceeding toward the top. Pollen is available for several days on *Anthurium* flowers because of the uneven maturation of individual pistillate flowers. A *Spathiphyllum* inflorescence also will produce pollen over a 2 to 3 day period (Henny 2000). *Anthurium* pollen is not dispersed by wind, but it can be transferred to the receptive flowers with the fingertips. *Spathiphyllum* pollen is lighter and tends to be

dispersed by air currents, so a brush should be used to collect it in a container before attempting pollination.

To achieve maximum seed production, an *Anthurium* spadix needs to be pollinated more than once, whereas it is possible to fertilize an entire *Spathiphyllum* spadix with one pollination. No special environmental manipulation is needed to ensure seed set for *Anthurium* or *Spathiphyllum*.

If pollen is in short supply, it can be stored in a refrigerator. *Philodendron* and *Spathiphyllum* pollen may be stored for several days or weeks in this manner (Henny 2000). *Aglaonema* and *Dieffenbachia* pollen is short-lived and germination ability declines within 1 to 2 days of storage (Henny 2000). It is best to use fresh pollen from those genera if possible.

Pollinated *Dieffenbachia* develop mature fruits within 10–12 weeks (Henny 2000). *Anthurium* fruit will require up to 6 months to ripen, while *Philodendron* fruit vary from 2 to 6 months depending on species. *Aglaonema* fruits mature in 4–6 months, although some hybrids have taken 1 year to develop ripe fruit. In *Dieffenbachia* and *Aglaonema*, the seed coat turns bright red when the seed is mature. *Anthurium* and *Spathiphyllum* spadices begin to change color and soften as seeds mature.

Bromeliad pollination is not difficult, but it does require close attention to the ripening of the stamens and to the pistil during the short period it may receive pollen. Normally, bromeliad flowers last but a few hours. Exceptions to this rule may be found in many of the Vriesea; if they blossom in cool weather the flower may remain receptive a second day. In some species, the stigma extends out beyond the stamens and such a flower is easy to pollinate, but in many species the stamens may exceed the pistil or may be of even length, which requires emasculation to avoid self-pollination. Pollen can be procured on a small camel hair brush that is used to deposit it on the selected stigma.

Dracaena produce flowers that are cream-colored, approximately 1–2 cm across and possess a single stigma and six stamens. Flowers are held on racemes that may be 30–50 cm long, open in early morning, and must be pollinated before they shrivel in early afternoon. A single raceme may hold 200 individual flowers.

The style and cucullate (hood-shaped) staminode distinguish *Calathea* (Marantaceae) from other families. The style is held under tension by the hood-shaped staminode, which has a trigger. The pollen is deposited in a shallow depression on the back of the style just behind the stigma. It is the upward growth of the style that forces the pollen grains from the anther, and onto the stylar depression. When the polli-

nator inserts its head into the flower in search of the nectar, it depresses the appendage, or "trigger," on the cucullate staminode, thus releasing the style, which springs forward bringing the stigma in contact with the pollen (from a previously visited flower) on the pollinator's body and in the same motion depositing its own pollen in the same spot. Manual pollination requires collecting pollen on the tip of a small needle and transferring it to the stigmatic tip of another flower, followed by placing pressure on back of the style, which triggers the style to spring forward, thus preventing visitation by an unwanted pollinator.

Although the juvenile forms of *Hedera helix* used as foliage plants do not flower, mature ivy has gray-green flower buds that appear on the tips of the twigs from mid-summer onward. The flowers open into umbels in September with yellow-green flowers that have five sepals, petals, and stamens. The flowers produce nectar for assorted insects such as wasps, honey bees, and moths that help with pollination. By the end of the year, many clusters of small, hard green berries have formed and, during January and February, they slowly swell and turn black (Rose 1996).

3. Ferns. Polypodiaceae (fern) is a difficult family to breed. Ferns sold as foliage plants or seen in landscapes are in the sporophyte generation of the plant's life. They reproduce by spores. When mature spores germinate, they produce a prothallium, a very small, flat, green, mosslike structure, which is the gametophyte generation. Sexual reproduction takes place during this generation. Fertilization occurs, and the next sporophyte generation develops when the prothallium is still small. During the gametophyte stage, archegonium (eggs) and antheridium (pollen sacs) are formed on the prothallium. The antheridium produces mobile antherozoids, that swim to the archegonium and fertilize the eggs when the prothallium is covered with a film of water. Techniques must be developed to introduce desired antherozoids of one species or variety onto the prothallium of another species to produce hybrids. These must be introduced at the proper time to allow fertilization of egg cells before antherozoids of the female parent are released from the prothallium. This task is very exacting and difficult so few people have undertaken hybridizing ferns.

C. Seed Handling

To achieve good germination, aroid seed should be separated from the spadix. Cleaning seeds speeds germination and lessens the chance of disease starting in the decaying fruit. For genera like *Dieffenbachia* and *Aglaonema* that have large seeds, the red berry-like fruit is harvested, and

the fleshy seed covering is removed. Genera with large numbers of small seeds, such as *Spathiphyllum*, are more difficult. It is easiest to harvest the entire spadix when mature (indicated by a change in color from green to yellow and a softening of the tissue) and placing it in a plastic bag with a little water. The spadix tissue will decay in a few days, allowing the seeds to be removed by gently washing them on a screen small enough to catch the seeds but letting the rotted spadix tissue fall through.

Once cleaned, seeds should be planted before becoming dry. Good germination is achieved if the seeds are sown on the top of moist medium and covered with plastic or some other material to prevent drying. Soil temperature should be kept at a minimum of 21°C. Aroid seed have no dormancy requirements and begin to grow as soon as sown. They can be removed from the germination chambers and repotted once the first true leaves are produced. Most aroid seedlings require at least 1–2 years before they are large enough to be evaluated for their ornamental value.

D. Testing and Releasing New Cultivars

At the University of Florida, if a desirable foliage plant is identified from a hybrid progeny, it is first propagated vegetatively for further testing. Plants of the hybrid are given to cooperating Florida tissue culture laboratories for establishment. Subsequently, the hybrid is distributed to trial growers around the state who evaluate the plant under commercial growing conditions. In addition, plants are given back to the University for evaluation of growth rate and tolerance to shipping and interior conditions. If the new clone performs well for the trial growers and in University trials, it is named, patented, and released. Industry participation in the propagation and testing process of foliage plant hybrids is critical in the development of new cultivars at the University of Florida.

IV. BREEDING OBJECTIVES

Breeding objectives with foliage plants include the improvement of traits related to ornamental value and stress resistance.

A. Phenotypic Traits

Because the value of foliage plants lies in the esthetic qualities, the improvement of ornamental traits, such as plant form, leaf shape, texture, plant height, shape, thickness, and color, as well as growth rate, has always been important to any breeding program of foliage plants.

1. Foliar Variegation and Colors. Variegated plants comprise about one-third of the ornamental plants grown commercially (Betrock 1996). Due to their magnificent multicolored leaves, variegated foliage plants, such as *Aglaonema*, *Calathea*, *Chlorophytum*, *Cordyline*, *Dieffenbachia*, *Dracaena*, *Epipremnum*, and *Syngonium*, are widely used in interior plantscapes. Consumer preferences for plant characteristics placed leaf variegation as the second most important consideration in the purchase decision (Behe and Nelson 1999). According to Kirk and Tilney-Bassett (1978), variegation can be categorized as either cell lineage or noncell lineage types. Cell lineage variegation occurs in genetic mosaics (individuals with cells of different genotypes), while in noncell lineage variegation, all cells have the same genotype but the genes responsible for the synthesis or destruction of pigments are expressed only in some of the cells (Marcotrigiano 1997). Noncell lineage variegation is expressed in *Aglaonema* and *Dieffenbachia* and in both genera the variegation patterns are inherited in simple Mendelian fashion (Henny 1983; Henny 1982; Henny 1986a). The common cause of noncell lineage variegation is the result of differential gene expression (Marcotrigiano 1997).

Inheritance of foliar variegation has been studied in *Caladium*, *Aglaonema*, and *Dieffenbachia*. A single dominant gene controls the netted venation pattern of *Caladium*, with the recessive genotypes having no pattern (Wilfret 1986). The red main vein in *Caladium* leaves is dominant to green, and white is dominant to both green and red. Red vein was also found to be epistatic to netted venation, in that the homozygous genotype for red veins produces a solid red leaf with a green margin (Wilfret 1986). Red and white leaf spots in *Caladium* are governed by codominant alleles (Wilfret 1986; Zettler and Abo El-Nil 1979).

The presence of foliar variegation in *Dieffenbachia* and *Aglaonema* is dominant to non-variegation. A single dominant allele (*Pv*) determines the presence of a variegation pattern typical for *Dieffenbachia maculata* 'Perfection' (Henny 1982). The same allele controls a similar pattern in *D. maculata* 'Hoffmannii' with slight differences due to modifying genes. A mutation of the *Pv* allele to Pv^1 produced the variegation pattern present in *D. maculata* 'Camille' (Henny 1986a). The Pv^1 allele masks expression of the *Pv* allele in plants containing both alleles.

Six different foliar variegation patterns of *Aglaonema* were governed by multiple alleles at a single locus (Henny 1983a, 1986b). Each distinct pattern was controlled by a separate dominant allele. Alleles were codominant, allowing expression of two variegation patterns in the same plant. Several other variegation patterns in *Aglaonema* currently being studied appear to be inherited in the same manner.

Studies in the inheritance of the white foliar midrib in *Dieffenbachia* show it is controlled by a single dominant gene (Henny 1983b) linked to the gene controlling foliar variegation. The dominant alleles for each trait were carried on homologous chromosomes.

2. Leaf Shape and Size; Petiole Colors. Some characteristic leaf shapes and sizes are particularly attractive and striking. Changes in leaf size and shape can create new and exciting appearances in hybrids and in aroids; such traits are under multigenic control. Petiole color in *Aglaonema*, which includes green, pink, white, and russet, is inherited independently of foliar variegation and appears to be due to the interaction of at least two genes.

3. Plant Form. Plant overall form has always been an important trait in foliage plants. There are six principal groups.

Upright. Plants such as *Dracaena fragrans* 'Massangeana' are defined as upright, with their dramatic tall and narrow form. Such plants have no hint of a spreading or trailing stem to soften the outline, even after several years of growth. They are suited to be placed in corners of rooms.

Compact or Clumping. This form is attributed to two common elements present in foliage plants, including basal shoot formation and dwarf growth habit. The tendency for plants to develop basal shoots, or suckers, is under multigenic control in *Anthurium* and *Dieffenbachia* (R. J. Henny unpublished). Highly suckering plants of both genera tend to transmit the trait to hybrids in varying degrees. Production of numerous basal shoots is a highly desirable trait in *Aglaonema*, *Spathiphyllum*, and *Dieffenbachia*. A cultivar with more basal shoots will need fewer cuttings per container to produce a full appearance. Additionally, basal shoots can be removed and used as propagules.

Trailing. Stems that cascade down or are prostrate are typical of such plants as *Hedera helix* and *Ficus pumila*. Stems of the spider plant (*Chlorophytum comosum*) strike upward initially then bend gracefully as they develop, giving the effect of a fountain. As plants start to mature, they produce propagules on the ends of stems that cascade down to make the plant a true trailer.

Climbing. A climber generally has limber stems that will trail if they are not supplied with support. They may have twining stems, clinging ten-

drils, or aerial roots to support them. Such plants include *Epipremnum aureum*, *Monstera deliciosa*, and *Philodendron scandens oxycardium*.

Standards. These are treelike plants that have a main stem and a branching head. *Ficus benjamina* is a popular example.

Architectural. The term "architectural" applies to forms that are unusual and dramatic. The shape and outline of such plants is bold and eye-catching. They are always large plants, tending to be tall rather than spreading, such as *Chamaerops humilis*, the European fan palm, which has big, boldly cut, fan-shaped leaves and sturdy, hairy roots.

4. Flowers. Foliage plants that are also commercially valued for their flowers include *Anthurium*, *Aphelandra*, Bromeliads, and *Spathiphyllum*. In *Anthurium*, two genes, *M* and *O*, are responsible for production of the five major spathe colors of *Anthurium andraeanum* (Kamemoto and Kuehnle 1996). The colors and their respective genotypes are: red (*MMOO*, *MMOo*, or *MmOO*); pink (*MmOo*); orange (*mmOo*, *mmOO*, or *mmoo*); coral (*mmoo*); and white (*mmoo* or *Mmoo*).

Breeding objectives concerning flowering foliage plants are to increase flower number and longevity and to expand the range of flower colors. In addition, the ability to continue flowering under interior conditions is important in *Anthurium* and *Spathiphyllum*. A six-month evaluation of five *Anthurium* cultivars under a light intensity of 16 μmol m^{-2} s^{-1} (Chen et al. 1999) showed that monthly new leaf growth ranged from 1.2 to 5.4 and new flower appearance from 1.4 to 4.7 among cultivars. 'Red Hot' showed the best flowering and growth performance with a weekly average flower count of 4.7 and 5.4 new leaves. The leaves were dark green and shiny, and the flowers were good quality. These large differences among cultivars in interior performance indicated there are good possibilities for selecting *Anthurium* cultivars that will continue to grow and flower under low interior light levels.

5. Fragrance. The consumer often desires fragrance in flowers. First generation progeny analyses from 22 crosses between non-fragrant and fragrant parents indicated that multiple genes govern scent characteristics in *Anthurium* (Kuanprasert and Kuehnle 1999). *Spathiphyllum* flowers are also naturally very fragrant for about a two-week period once the spathe opens to expose the spadix. However, no specific breeding work has been done with fragrance as a goal for *Spathiphyllum*.

6. Growth Rate. Foliage cultivars vary in growth rate. *Anthurium* 'Krypton' produced a dry weight of 38 g, whereas *A.* 'Tropic Fire' had a dry

weight of 24 g when both began with the same fresh weights and were grown under identical conditions for 8 months (Chen et al. unpublished). *Dieffenbachia* 'Tropical Star' became marketable one month earlier than *D.* 'Snowflake' and *D.* 'Exotica Perfection' when grown under an ebb-and-flow fertigation system in which fertilizer and water supplies were controlled (Chen et al. unpublished). Many foliage plants grow slowly, so improving growth rate (i.e., reducing the time from transplanting to finishing) will reduce production time and increase profits.

B. Stress-related Traits

Foliage plants often experience physical, chemical, and biotic stresses in both production and interiorscaping. These stresses include drought, high or low temperatures, inappropriate radiation, low or excessive nutrient levels, agrochemicals, disease, and pests. The important stress-tolerance traits in foliage plant production and utilization are listed below.

1. Adaptation to Interior Environments. The ability of foliage plants to adapt to interior environments and maintain their esthetic appearance is one of the most important traits (Chen et al. 2001b). Indoor selection criteria designed for evaluating a plant's interior performance in our program include a light intensity of 8 or 16 μmol m^{-2} s^{-1} for 12 hr a day, a temperature from 20 to 24°C, relative humidity of 40 to 50%, and a CO_2 concentration of 600 μL L^{-1}. Interior performance is evaluated using several traits, including leaf yellowing, leaf drop, loss or reduction in foliar variegation, elongation of internodes (i.e. stretching), changes in overall plant configuration or form, change in leaf or flower color, flower longevity, loss of flowering, or development of physiological disorders, diseases, or pests. Good interior plants should be able to maintain their esthetic appearance for at least six months after installation in the interior environment.

Light intensity is the most crucial factor that limits plant performance in interior environments. Plants that can be maintained under 8 μmol m^{-2} s^{-1} can be used in low light areas such as offices, hotel hallways, or corners of conference rooms. Those maintained under 16 μmol m^{-2} s^{-1} are suitable for higher light locations such as airport waiting areas, malls, or bright living rooms.

General information with regard to the interior performance of common foliage plant genera is available (Manaker 1997), but the genetic mechanisms underlying their adaptation to the indoor environment are

largely unknown. Plants tolerant to the lowest light levels include *Aglaonema*, *Calathea*, *Dracaena*, *Epipremnum*, *Nephrolepis*, and *Syngonium*. However, other genera contain species or cultivars that express different tolerances to interior low light conditions. For example, newly released *Dieffenbachia* 'Snowflake' exhibited much better interior performance than the more common 'Perfection Compacta' (Chen et al. unpublished data). Cultivars with better interior performance could be potential parents for breeding future hybrids.

2. Disease and Insect Resistance. Foliage plant production requires a warm and humid environment. These are ideal conditions for rapid increase and spread of bacterial, fungal, and viral diseases. Disease problems are more common in production than in interiors where conditions are cooler and drier. Most fungal diseases are controlled with fungicides, but chemical controls are usually ineffective against bacteria or viruses (Chase 1997). Plants infected with bacteria or viruses must be destroyed and only clean materials should be used as a source of propagules (Chase 1981).

In an attempt to reduce chemical use in nursery crop production, breeding for disease resistance has become one of the major objectives in foliage plant improvement. With the availability of diverse plant species or cultivars, a wide range of resistance has been identified in many foliage plant genera. Resistant accessions can be used as donors for improving disease resistance. Current programs at the University of Florida include breeding for resistance in *Anthurium* to *Xanthomonas* bacterial rot (Norman et al. 1999a), *Spathiphyllum* to *Cylindrocladium* fungal root and petiole rot (Norman et al. 1999b), and *Syngonium* to *Myrothecium* fungal leaf spot (Norman and Henny 1999). Breeding efforts at the University of Hawaii include the improvement of *Anthurium* resistance to *Xanthomonas campestris* pv. *dieffenbachia* and the nematode *Radophlus similis* (Kuehnle et al. 2001; Wang et al. 1998).

Insect and mite problems can develop rapidly in large populations of foliage plants. The major insect pests for foliage plants include aphids, caterpillars, mealybugs, scales, and thrips (Hamlen et al. 1981; Baker 1994). Adequate chemical controls exist for most insect and mite problems and, if crops are routinely monitored, good control is possible (Short et al. 1999). Use of pest-free propagules and maintenance of sanitary conditions in production areas are essential for reduction of potential pest problems (Hamlen et al. 1981). The great challenge to insect control, however, is foliage plants in interior environments such as public conservatories, homes, hotels, office buildings, restaurants, shopping malls, hospitals, and schools where few chemicals have been

cleared for interior plant use. The best long-term solution is the development of cultivars that resist infestation in interior environments. Chen et al. (2001d) evaluated resistance of different *Anthurium* cultivars to infestation of either banded greenhouse thrip (*Hercinothrips femoralis*) or two-spotted spider mite (*Tetranychus urticae*) in interior conditions. Cultivars strongly resistant to one pest were not resistant to the other. However, some cultivars showed moderate resistance to both pests, suggesting that genetic improvement of resistance to the banded greenhouse thrip and the two-spotted spider mite is possible.

3. Temperature Tolerance. Because of their tropical or subtropical origin, foliage plants are sensitive to chilling temperatures. Chilling in foliage plants is defined as a temperature that is cold enough to cause injury but not cold enough to freeze the plant tissue, usually ranging from just above 0° to 15°C (Chen et al. 2001e). Chilling injury can be visible, ranging from water-soaked patches or necrotic lesions on leaves and also invisible, mainly in reducing plant growth rate. For example, chilling injury on *Spathiphyllum* appears at 7°C with injured leaves becoming necrotic and dry. There is no visible injury immediately following exposure to 10°C, but plant growth index can be reduced by up to 50%, depending on cultivar as a delayed expression (Qu et al. 2000). *Aglaonema* injury occurs at 13°C, characterized by dark and greasy-appearing patches on the surface of leaves (Chen et al. 2001a). Tissue collapse in older leaves is a typical symptom in *Dieffenbachia* (Conover and Poole 1974).

Chilling injury is a significant cause of loss of foliage plants not only in production, but also in transportation and interiorscaping. Chilling injury accounts for nearly 50% of all transportation damage claims (Conover 1980). After evaluating 22 species in simulated shipping experiments, Poole and Conover (1993) concluded that the best shipping temperatures are in the range of 15 to 18°C. Chilling injury to interior plants often occurs when interior temperatures fail to maintain an appropriate level either in winter or summer (Manaker 1997).

Genetic variation in chilling resistance exists in foliage plants. Chen et al. (2001a) evaluated 10 *Aglaonema* cultivars and found that 'Silver Queen', one of the most popular cultivars in the foliage plant industry, was extremely sensitive to chilling. 'Silver Queen' had 30% of leaves injured 10 days after chilling plants to 13°C. 'Maria', a cultivar well known for its chilling resistance, was not the most resistant one tested. Ten days after chilling at 2°C, 32% of Maria's leaves were injured, but there was no discernable injury on 'Emerald Star', 'Stars', or 'Jewel of India', three recently released hybrids. Use of resistant cultivars may

greatly reduce chilling injury instances during production and transportation and also conserve energy used during the greenhouse production phase.

V. FOLIAGE EXAMPLES

The following discussion will focus on cultivar development of important genera. These genera collectively account for at least 60% of the total U.S. wholesale value of ornamental foliage plants (USDA 1998). Cultivars may originate from plant collection, traditional breeding, and selection of mutants from traditional propagation or from somaclonal variants generated from tissue culture.

A. Aroids (Araceae)

1. *Aglaonema.* The genus *Aglaonema*, commonly referred to as Chinese evergreen, is comprised of 21 species native to southeast Asia, from northeastern India, across southern China, into Indonesia and New Guinea (Mayo et al. 1997). Most *Aglaonema* species are open-pollinated; a few may exhibit apomixis, such as *Aglaonema costatum* 'Foxii'. Propagation of *Aglaonema* is by seeds or vegetative tissue, mainly by tip cuttings or division. The basic number of chromosomes could be $x = 6$, with subsequent polyploidy in many cases (Jones 1957). Both *Aglaonema haenkii* and *A. simplex* have a $2n$ chromosome number of 60, and *A. commutatum* has $2n = 120$ (Jones 1957). However, $2n$ chromosome number of 40 was also reported in *A. pictum* Kunth and *A. oblongifolium* (Kunth) Schott. (Marchant 1971). Speculations on the difference in chromosome numbers among *Aglaonema* species include chromosome doubling and even dysploidy (Tischler 1954).

Aglaonema is one of the most widely used plants in interiorscape due to its ability to tolerate low light and low humidity and its resistance to diseases and pests. The number of commercial cultivars increased from 10 in 1975 to 36 at the end of the 1990s (Table 6.3). Commercial growers add and discard cultivars on a regular basis. For example, when cultivars listed in the FNGA (Florida Nurserymen and Growers Association) Locator 1998–1999 and 1999–2000 are compared, five cultivars listed in 1998–99 were no longer listed, and four new cultivars were added in 1999–2000. Almost all *Aglaonema* cultivars are hybrids developed through traditional breeding. Current breeding activities are mainly focused on generating novel foliar variegation patterns, petiole colors, increased branching, and chilling resistance (Henny 2000).

Table 6.3. Changes in cultivar numbers of major foliage plant genera or groups in commercial production of Florida.[z]

Foliage plant	1975	1988–89	1998–99
Aglaonema	10	17	36
Alocasia	0	2	14
Anthurium	0	12	36
Calathea	3	14	21
Dieffenbachia	7	29	23
Dracaena	12	21	33
Epipremnum	3	4	4
Fern	10	21	54
Ficus	14	32	46
Hedera	1	12	40
Palm	7	19	22
Philodendron	16	24	18
Spathiphyllum	4	24	51
Syngonium	7	14	17

[z]FNGA (Florida Nurserymen and Growers Association) Locator 1975, 1988–1989, and 1998–1999, Orlando, FL.

Aglaonema hybrids are almost exclusively selected from interspecific hybridization. Species commonly used in interspecific hybridization include *A. nitidum*, *A. commutatum*, *A. costatum*, and *A. rotundum*. The most common hybrids grown in Florida from the 1960s to the 1980s were *Aglaonema* 'Fransher' (*A. treublii* × *A. marantifolium* tricolor), *A.* 'Parrot Jungle', and *A.* 'Silver King' (*A. curtisii* × *A. commutatum* 'Treubii'), developed by Nat Deleon of Miami, Florida, and *A.* 'Silver Queen' (*A. commutatum* 'Treubii' × *A. nitidum* 'Curtisii'), developed by Bob McColley of Bamboo Nursery in Orlando, Florida.

Currently popular hybrids come from breeding programs at the University of Florida's MREC in Apopka and also from southeast Asia, for example, India, Indonesia, and the Philippines. MREC hybrids include *Aglaonema* 'Silver Bay' (Henny et al. 1992a) that has a medium green edge overlaid with a gray-green center. 'Golden Bay' (Henny and Chen 2001) is a white-stemmed cultivar and has very bright cream and green color variegation. 'Emerald Bay' has a white and green speckled stem, while 'Diamond Bay' displays a clear central gray stripe against a dark green leaf blade (Henny et al. 2002a). Sunshine Foliage World, Zolfo Springs, Florida, introduced 30 new cultivars developed by breeders in Thailand. These cultivars, including 'Jubilee Petite', 'Peacock', 'White Rain', 'White Lance', 'Brilliant', 'Illumination', 'Black Lance', 'Green Lady', 'Patricia', and 'Stars', have different sizes, shapes, and

variegation patterns of leaves and white, green, or pink petioles. 'Emerald Star' and 'Jewel of India' are two cultivars developed by breeders in India.

2. *Alocasia*. This genus of 70 species is native to southeast Asia from India to the Philippines and New Guinea (Bailey and Bailey 1976). Common species used as foliage plants include *A. cucullata*, *A. cuprea*, *A. indica*, *A. longiloba*, *A. lowii*, *A. macrorhiza*, *A. portei*, *A. sanderiana*, *A. thibautiana*, *A. veitchii*, *A. watsoniana*, and *A. zebrina*. *Alocasia cucullata* and *A. macrorhiza* are giant taro, cultivated also for their edible rhizomes. Chromosome number of most species are $2n = 28$, but *A. odora* is $2n = 56$, and *A. lowii* is $2n = 70$, suggesting that the basic number of chromosomes is $x = 7$ (Marchant 1971).

Alocasia has unisexual flowers. Hybrid alocasias have been known for about 100 years and were first produced by European horticulturists (Reark 1951). Hybrids that were popular in the 1950s were *A.* × Amazonia (*A. lowii* Var. Grandis × *A. sanderiana*), *A.* × Cantrieri (*A. cupera* × *A. sanderiana*), *A.* × Sedenii (*A. lowii* × *A. sanderiana*), and *A.* × Mortefontainensis (*A. lowii* × *A. sanderiana*). Seed production is one method of propagation, but the common method is through division of offsets.

Even though alocasias are valued for their variegated colorful leaves, they were not included in a recent book *Tropical Foliage Plants: A Grower's Guide* (Griffith 1998b). Recent renewed interest in alocasias is largely due to the release of more than 40 new cultivars in the last four years. These cultivars are somaclonal variants and have different colors, shapes, and sizes of leaves embellished with unique variegation, providing valuable additions for interiorscaping. The most notable cultivars include 'Bako Park', 'Black Stem', 'Black Velvet', 'Corozon', 'Elaine', 'Fantacy', 'Frydek', 'Grandis', 'Nobilis', 'Polly', 'Purple Prince', 'Sarian', 'White Knight', and 'Wentii'. Because of the effectiveness of tissue culture in generating desirable mutants, cultivar development in *Alocasia* now relies primarily on the selection of somaclonal variants.

3. *Anthurium*. This is the largest genus in the Araceae, consisting of about 1000 species (Croat 1992). The distribution of this genus ranges from northern Mexico and the Greater Antilles to southern Brazil, northern Argentina, and Paraguay (Croat 1983, 1986). *Anthurium*s are valued for their exotic shape, colorful spathe and spadix with great longevity, and also the attractive foliage of some species. Species from this genus have been used commercially as cut flowers, potted flowering foliage, or potted foliage plants. *Anthurium* has bisexual flowers and, in many species, emit odors while blooming. Therefore, *Anthurium* species are

largely cross-pollinated by insects. Propagation can be performed through either seed, division, or tissue culture.

Commercial cultivars used for cut-flower production are mainly from species of *A. andraeanum*, whereas potted flowering cultivars were initially derived from *A. scherzerianum* (Kamemoto and Kuehnle 1996). Species that are produced for their attractive foliage include *A. warocqueanum*, *A. crystallinum*, and *A. magnificum*. Some species, such as *A. armeniense*, *A. fragrantissimum*, and *A. lindenianum*, emit a pleasant fragrance (Kuanprasert and Kuehnle 1999), and these species may be useful for breeding for floral fragrance.

Because of its richness in germplasm resources and economic importance as cut flowers, potted flowering foliage, or potted foliage plants, *Anthurium* is probably the most widely studied genus in relation to cultivar development. Areas of investigation include plant collection and identification (Croat 1983, 1986), isozymes or DNA markers for relatedness determination (Kobayashi et al. 1987; Ranamukhaarachchi et al. 2001), plant introductions (Dressler 1980; Kamemoto and Kuehnle 1996), liquid raft culture conservation of germplasm (Kuehnle, personal communication), traditional breeding (Kamemoto and Kuehnle 1996; Henny 2000), micropropagation (Matsumoto and Kuehnle 1997), somatic embryogenesis (Kuehnle et al. 1992), protoplasm fusion (Kuehnle 1997), and genetic transformation (Kuehnle et al. 2001).

In most species studied, the chromosome number is $2n = 30$ (Sheffer and Kamemoto 1976a; Sheffer and Croat 1983). Pollination between *A. andraeanum* and *A. scherzerianum* has never been successful due to their distant relationship since *A. andraeanum* belongs to the section *Calomystrium*, but *A. scherzerianum* is from the section *Porphyrochitonium* (Kamemoto and Sheffer 1978; Sheffer and Kamemoto 1976b). The discovery of *A. amnicola* Dressler, a species belonging to the section *Porphyrochitonium*, was made in Cocle del Norte, Panama, in 1972 by Dressler (1980) at the Smithsonian Tropical Institute in Balboa, Panama, and its introduction to cultivation made a great difference in potted *Anthurium* cultivar development. The plant is not only compact and attractive but also can be easily crossed with species from the section *Calomystrium*, including *A. andraeanum*. Another species, *A. antioquiense*, also belonging to section *Porphyrochitonium*, was found on the Pacific coast of Colombia. In addition to its desired phenotype and crossability like *A. amnicola*, this species is also tolerant of the bacterial blight caused by *Xanthomonas campestris* pv. *dieffenbachiae*. Currently, most breeding programs for potted *Anthurium* cultivar development use *A. antioquiense* and *A. amnicola* as parents because both species are dwarf and highly floriferous (Kamemoto 1981; Kamemoto

and Sheffer 1978). These species cross with species from section *Calomystrium* such as *A. andraeanum* and yield interspecific hybrids with a wide range of spathe colors. One example is *Anthurium* 'Red Hot' (Henny 1999), which was developed from an initial interspecific cross of *A. andraeanum* with *A. amnicola*. 'Red Hot' branches freely and exhibits a compact growth habit with each pot averaging five red flowers. It is now one of the most popular cultivars in the foliage plant trade. The reader is referred to *Breeding Anthuriums in Hawaii* by Kamemoto and Kuehnle (1996), an excellent treatise on breeding for cut flower and potted *Anthurium* use.

In addition to traditional breeding, tissue culture propagation of interspecific hybrids has led to the selection of a large number of somaclonal variants and subsequent release of many new *Anthurium* cultivars. Oglesby Plants International, Inc., Altha, Florida, successfully introduced the Lady series starting with 'Lady Jane' in 1985, followed by 'Lady Anne', 'Lady Beth', and 'Lady Carmen'. All the Lady series are dwarf and compact cultivars with deep green lanceolate foliage contrasting to either white, pink, or red spathes; the Lady series rapidly gained market share as potted flowering foliage plants. Potted *Anthurium* cultivar development is also extremely active in Europe, especially in the Netherlands, but information on breeding and cultivar development is not readily available.

Anthurium is the only foliage plant genus thus far that has been genetically transformed. Kuehnle and Sugii (1991) presented the first evidence of tumor formation and nonpaline production in *Anthurium andraeanum* Hort. when co-cultivated with *Agrobacterium tumefaciens* strains A281 and C58 in an induction medium containing acetosyringone. Subsequently, using nontumorigenic *Agrobacterium* strain LBA4404, containing the *vir*-helper plasmid (*pAL4404*) in strain Ach5 chromosomal background, Kuehnle et al. (2001) developed an effective method for transformation of different *Anthurium* cultivars. Testing transgenic plants expressing the *att* gene showed greater decreases in symptoms and in the number of inoculated *Xanthomonas campestris* pv. *dieffenbachiae* strain D150 compared to the control plants (Kuehnle et al. 2001). The successful transformation of *Anthurium* offers additional avenues for improving cultivars of not only this genus but also other important aroid genera discussed in this review, and possibly foliage plant genera from other families.

4. *Dieffenbachia.* The genus *Dieffenbachia*, commonly known as dumb cane, is composed of about 30 species native to moist, lowland tropical forests of Central and South America (Bailey and Bailey 1976). Flowers

are unisexual with dichogamy in nature; thus, *Dieffenbachia* is predominately cross-pollinated. The chromosome number of most *Dieffenbachia* species is $2n = 34$ (Jones 1957). A significant amount of *Dieffenbachia* propagation has shifted from tip cuttings to tissue culture, partly in an attempt to develop stock plants free of systemic bacteria and viruses. Through hybridization and selection of sports and somaclonal variants, almost 100 cultivars have been introduced over the years, of which only about 20 cultivars are grown commercially (Table 6.3).

Interspecific hybridization is the primary means of generating new cultivars. Inheritance of foliage variegation has been shown to be dominant to non-variegation and a single dominant allele (*Pv*) in interaction with modifying genes determines variegation pattern of *D. maculata* (Henny 1982, 1986a). Basal shoot formation is controlled by multiple genes. Breeding programs have been focused on the improvement of variegation patterns concomitant with increased basal shoot formation. Nine hybrids have been released at the University of Florida including 'Triumph', 'Victory', 'Tropic Star', 'Starry Nights', 'Star White', 'Star Bright', 'Sparkles', 'Tropic Honey', and 'Sterling' (Henny et al. 2003b). These hybrids have different variegation patterns, large leaves with short petioles, and, in most cases, they produce basal shoots freely. E. J. Frazer in Brisbane, Australia, bred several hybrid cultivars, including 'Tropic Breeze', 'Tropic Rain', 'Tropic Dawn', and 'Tropic Forest', that have been introduced into the foliage plant industry by Twyford International Inc., Apopka, Florida.

Selection of sports is another avenue of cultivar development in *Dieffenbachia*. At least 11 patented cultivars were selected from spontaneous mutations (Table 6.3). Most of them were derived from *D. amoena* and *D. maculata*. For example, 'Tropic Snow' is a sport of *D. amoena*, and 'Tropic Sun' and 'Maroba' are sports of 'Tropic Snow'. Cultivar 'Marianne' is a mutant of *D. maculata* 'Perfection Compacta'; 'Camille' is a sport of 'Marianne'.

As tissue culture becomes a routine method of *Dieffenbachia* propagation, more somaclonal variants have been generated. Selection of a desired somaclonal variant has proved to be a more effective way of cultivar development. For example, 'Rebecca's Jewel' was selected from somaclonal variants rising from tissue culture of *D. maculata* 'Camille'.

5. *Epipremnum*. *Epipremnum* (pothos) is indigenous to southeast Asia and the Solomon Islands (Huxley, 1994). *Epipremnum* has about 10 species (Bailey and Bailey 1976), but only *E. aureum* is widely grown. In fact, *E. aureum* is one of the most popular houseplants worldwide. Pothos has unisexual flowers and is propagated primarily by single or

double eye cuttings. Tissue culture has not been used commercially, and there is no information in the literature regarding pothos breeding. Three cultivars ('Golden Pothos', 'Marble Queen', and 'Jade') have been dominant in the market for decades. The only new cultivar recently released is 'Neon' with uniform yellowish-green foliage. Qu et al. (2002) successfully regenerated pothos from petiole and leaf explants. There is potential for developing somaclonal variants by screening explants generated from tissue culture.

6. *Philodendron.* The genus *Philodendron* contains 700 or more species, making it the second largest genus in the Araceae (Croat 1997). Philodendrons are native to tropical America and comprise a conspicuous component of the native flora because of their abundance, climbing habit, and large, showy leaves. *Philodendron* formerly dominated all other genera of tropical ornamental foliage plant production, accounting for 50% in 1950 and 36% in 1967 of the national wholesale value of foliage plants in the United States (Smith and Strain 1976; McConnell et al. 1989).

Documented interspecific hybridization within the genus *Philodendron* dates to 1887 in Florence, Italy (Wilfret and Sheehan 1981) with the production of *P. corsinianum* (*P. lucidum* × *P. cariaceum*). The first U.S. hybrid, *P. mandaianum* (*P. hastatum* × *P. erubescens*) was developed by Manda in 1936. Beginning in 1951, most *Philodendron* breeding was conducted by Bob McColley of Apopka, Florida. He classified *Philodendron* into three groups based upon the sexual compatibility of the species (McColley and Miller 1965). The first is the self-heading group, growing upright on their own, which is represented by *P. wendlandii* and the hybrid 'Black Cardinal'. The second group is the erect-arborescent type, such as *P. selloum*, which appear self-heading when young, but assume more woody and treelike as they mature. While plants within each group cross freely, no successful crosses have been made between the two groups. This is in part because the chromosome number in the first group is $2n = 34$ but $2n = 36$ in the second group (Jones 1957). The third group is the vining or scandent type, such as *P. scandens oxycardium* (heartleaf philodendron); it is commonly grown as hanging baskets. The chromosome number of *P. scandens oxycardium* is $2n = 32$ (Jones 1957). *Philodendron scandens* has not been successfully self-pollinated or crossed with any plants from the first two groups, indicating that it may be sterile. McColley made about 30 interspecific hybrids using the self-heading species. Some of his hybrids, such as 'Autumn', 'Black Cardinal', 'Imperial Green', 'Imperial Red', 'Moonlight', 'Prince of Orange', 'Red Empress', and 'Red Emerald', are still popular.

7. *Spathiphyllum.* *Spathiphyllum*, commonly called peace lily, is one of the most popular foliage plants in the trade due to its dark green foliage, long-lasting showy white flowers, and ease of growing. Peace lily originates in the damp, tropical forest habitats of the Americas, the Philippines, and Indonesia (Mayo et al. 1997). Its survival in the tropical forest understory has enabled it to adapt to interior low light conditions. *Spathiphyllum* has bisexual flowers and is naturally pollinated by bees (Williams and Dressler 1976). The chromosome number of *Spathiphyllum* is $2n = 30$ (Jones 1957). Plants are propagated either through seeds, division, or tissue culture.

Spathiphyllum is a typical example of how a valuable foliage plant can be quickly accepted by the foliage plant industry. In the early 1970s, there were only two cultivars available: 'Clevelanii' and 'Manua Loa'. Now, the number of *Spathiphyllum* cultivars exceeds 50 in Florida alone (Table 6.3). The surge of new cultivars is largely attributed to traditional breeding, creation of interspecific hybrids, and selection of somaclonal variants from tissue culture. Cultivars may be divided into three classes based on plant size (Griffith 1998b): large, medium, and small. 'Sensation' is the largest cultivar in production at about 1.5 m tall. It was the result of a cross of 'Mauna Loa Supreme' and 'Fantastica'. The largest cultivars are usually grown in containers with a diameter of 24 cm or larger. The medium-size cultivars are generally produced in containers from 15- to 25-cm in diameter. Among them, 'Tasson' (derived from a cross of 'Manua Loa' and 'Wallisii') was popular for at least 10 years. The small-size cultivars (i.e., 'Petite') are usually grown in containers 15 cm in diameter or smaller.

8. *Syngonium.* *Syngonium*, whose name refers to the cohesion of the plant ovaries in Greek, has been a popular houseplant genus for many years. *Syngonium*, commonly known as arrowhead vine or nephthytis, is native to the region from Mexico to Panama and consists of about 33 species (Croat 1982), but only one species (*S. podophyllum*) is cultivated. Chromosome counts are $2n = 24$, 26, 28, or 30 (Marchant 1970; Pfitzer 1957; Sharma 1970). Flowers are unisexual, and inflorescences are protogynous, becoming receptive 1–2 days before the staminate flowers shed pollen (Croat 1982). As mentioned earlier, cultivars are largely selected from somaclonal variants rising from tissue culture. Current breeding research at the University of Florida is aimed at developing *Syngonium* hybrids resistant to fungal and bacterial diseases (Norman et al. 2002). Screening work is being conducted using 15 *Syngonium* species and 20 accessions. *Syngonium* flowers can be induced by gibberellic acid (GA_3) sprays (Henny et al. 1999), and its use is necessary to obtain simultaneous flowering of different species.

B. Bromeliads (Bromeliaceae)

Bromeliaceae have more than 50 genera containing more than 2,700 species native to tropical North and South America (Benzeng 2000). Their exotic appearance, graceful symmetry, and potential for year-round flowers make bromeliads profitable as ornamentals. Plants can remain in bloom for weeks or months under interior conditions. The rise in importance of Bromeliads has been recent, since they were not listed in 1988 as a major group of foliage plants in the Census of Horticulture Specialties of the U.S. Department of Agriculture's National Agricultural Statistics Service (McConnell et al. 1989). However, they were listed in 1998 and now account for 5.1% of the total national foliage plant wholesale value (USDA 1999).

Most species of Bromeliaceae are predominately outcrossing (McWilliams 1974). Protogyny occurs in species of *Tillandsia*, protandry in *Vriesea*, self-incompatibility in *Ananas*, and even dioecy in some species of *Catopsis* (Benzeng 2000). Some species cultivated by ants (e.g., *Aechmea mertensii* and *A. tillandsioides*) regularly set self-seeds (Madison 1979). A few species of *Guzmanala*, such as *G. graminifolia*, are also selfed under natural conditions. Bromeliads that are produced as foliage plants come primarily from the genera *Aechmea*, *Cryptanthus*, *Guzmania*, *Neoregelia*, *Nidularium*, *Tillandsia*, and *Vriesea*. Species of *Aechmea*, *Guzmania*, *Neoregelia*, *Nidularium*, *Tillandsia*, and *Vriesea* are largely epiphytic, while species from *Cryptanthus* are mostly terrestrial. The chromosome number of the previously listed seven genera is predominately $2n = 25$, with exception of *Cryptanthus*, which is $2n = 34$ (Marchant 1967). Bromeliads may be propagated from seeds, offsets (lateral shoots or suckers), or tissue culture.

Breeding of bromeliads started in Europe in the late 1880s. Eduard Morren did his first cross between *Vriesea psittacina* and *V. carinata* in 1879, which resulted in *V.* 'Morrenian' (Samyn and Thomas 1997). Hybridization and progeny selection were popular in Europe, especially in Belgium, France, Germany, and the Netherlands. Breeding of bromeliads in the United States among breeders, collectors, and hobbyists started in the early 1990s. Henry Nehring (1853–1929) described bromeliads grown in Florida. Julian Nally and Nat Deleon were among the earlier breeders who developed many hybrids in the United States. Most hybrids are selected from progenies of interspecific crosses. Intergeneric crosses between *Cryptanthus beuckerii* and *Billbergia nutans* have been successful, but the flowers have no ornamental value. Thousands of hybrids have been developed in the last 20 years. The Bromeliad Society International produced its first checklist of hybrids entitled *International Checklist of Bromeliad Hybrids*. The Bromeliad

Cultivar Registry (BCR), compiled by Don A. Beadle (1998), lists all registered hybrids.

C. *Calathea* (Marantaceae)

Calathea is the largest genus in the family Marantaceae and is composed of 100 species native to tropical America in moist to swampy forest habitats (Bailey and Bailey 1976). Most calatheas are grown for their brilliant patterns of leaf color, texture, and elegance. Only *C. crocata* is produced for both its foliage and erect orange-red flowers. The showy portion of the flower usually consists of sterilized, often petaloid staminodes, and pollination is performed by bees (Kennedy 1973). Most species are cross-pollinated, with a few that are truly cleistogamous such as *C. panamensis* (Kennedy 1973). Reported chromosome numbers include $2n$ = 18 for *C. albertii*, $2n$ = 16 for *C. cylinerica*, and $2n$ = 22, 24, 26, and 28 for *C. nigricans*, *C. picturata*, *C. leucostachys*, and *C. musaica*, respectively (Bisson et al. 1968; Mahanty 1970). *Calathea* propagation is traditionally from division, but cultivars of *C. picturata*, *C. vandenheckei*, and *C. argentea* can be propagated from seeds. Some cultivars are now propagated through tissue culture.

In 1975, only three species (*C. insignis*, *C. makoyana*, and *C. roseo-picta*) were commonly grown (Table 6.3). Now, more than 12 species are in cultivation. The collection and introduction of new species not only expanded the number of cultivars in the foliage plant trade but also greatly broadened the genetic resources of *Calathea* for breeding. Marantaceae expert Dr. Helen Kennedy discovered 11 new species of *Calathea* in Panama and Costa Rica (Kennedy 1973). Interspecific hybridization by plant hobbyists and collectors have contributed significantly to the cultivar development. *Calathea* 'Royale' is a hybrid selected from a cross of *C. roseo-picta* and *C. veitchiana*. The leaves have a bluish-green upper surface and a yellow to silver band fans around the margin, and a light green pattern spreads along the midrib. The lower leaf surface is rich burgundy. Other popular interspecific hybrids include *C.* 'Odora', *C.* 'Corona', and *C.* 'Medallion'. At least three cultivars ('Cora', 'Silvia', and 'Angela') were developed by selection of sports from *C. rose picta* by Magdalena J. M. van Rijn of the Netherlands. *Calathea* now is largely propagated through tissue culture. This has led to a number of new cultivars originating as somaclonal variants that were selected by tissue culture companies (Twyford Plant Laboratories, Inc., and Agri-Starts, Inc.) located in Apopka, Florida. These new cultivars include 'Dottie', 'Saturn', 'Eclipse', 'Rosy', 'Artic Blush', 'Helen', 'Corona', 'Cynthia', 'Loeneri', 'Maria', 'Picta Royale', 'Rosy Roseo Picta', 'Tigrinum', and 'Wilson's Princep'.

D. *Dracaena* (Dracaenaceae)

Dracaena encompasses 60 species, all of which, except *D. americana*, are indigenous to tropical Africa and Asia (Hutchinson 1986). Hutchinson (1959) assigned *Dracaena* to Agavaveae, but Takhtajan (1980) placed it in a separate family, Dracaenaceae. Recent phylogenetic analyses using internal transcribed spacer (ITS) rDNA sequences of 40 taxa in Agavaceae justified this placement in Dracaenaceae (Bogler and Simpson 1996).

Most species of *Dracaena* develop inflorescences consisting of loose umbels or clusters of greenish-white or cream-colored flowers, sometimes delightfully scented. The panicle is terminal and bracteate with two or more flowers per bract. Flowers are bisexual and small. Cross-pollination occurs naturally in the wild. The chromosome number of *D. draco* is $2n = 40$, while the chromosome numbers for other *Dracaena* species are unknown (Borgen 1969). Plants are propagated by either tip or cane cuttings.

Seven *Dracaena* species are grown mainly as foliage plants: *D. cincta*, *D. deremensis*, *D. fragrans*, *D. marginata*, *D. reflex*, *D. sanderiana*, and *D. surculosa* (*godseffiana*). These species are particularly favored by interiorscapers because of their diverse shapes, colors, forms, and growth habits and their ability to survive under low-light conditions for extended periods. There is no known organized breeding program devoted to *Dracaena*, and the increase of cultivars is predominately due to the selection of sports by commercial growers. *Dracaena fragrans* appears to sport frequently since six cultivars ('Kanzi', 'Jelle', 'Lemon Surprise', 'Golden Coast', 'White Jewel', and 'Janet Craig Gomezii') have been patented. Variability in the variegation patterns has also been exploited in *D. deremensis*. The cultivar 'Warneckii' has lanceolate leaves with milky thin bright green margins. 'Bausei' differs only in having a narrower center with the white bands closer together. Leaves of 'Roehrs Gold' have a broad yellow center, bordered by white lines and edged with green, and 'Janet Craig' is a green sport of this species. Other characteristics have been selected, such as the pendant corrugated leaves of 'Lognii'.

One interspecific hybrid, *Dracaena masseffiana* (*D. massangeana* × *D. godseffiana*), was developed in the 1800s. This hybrid is sterile, has almost no ornamental value, and is not grown commercially. We have treated this plant with colchicine in vitro but have not yet produced any fertile explants (Henny, unpublished research). One ex-plant was found with a very high degree of foliar variegation and is being evaluated for possible release (Henny, unpublished). Foliar variegation in sports of *D. fragrans* 'Massangeana' is chimeral and not seed transmitted. All offspring from self-pollination of this cultivar lack foliar variegation.

E. Ferns (Polypodiaceae)

Fern refers to a group of primitive plants belonging to the Division Pteridophyta that have specialized vascular systems but are seedless and flowerless. It has been estimated that 10,000 to 12,000 species and 230 to 250 genera of fern exist throughout temperate and tropical zones (Huxley 1994). The genera *Adiantum*, *Asplenium*, *Cyrtomium*, *Davallia*, *Nephrolepis*, *Platycerium*, and *Pteris* are cultivated as foliage plants. Gametophytic chromosome numbers (*n*) of *Adiantum* 30, 60, 90, 120, and 180 (Singh and Roy 1969; Verma and Goloknath 1967), *Asplenium* 36, 72, and 108 (Lovis 1968; Morzenti 1967), *Cyrtomium* 41, 82, and 123 (Mitui 1968), *Davallia* 40 (Dujardin and Tilquin 1971), *Nephrolepis* 41 (Roy et al. 1971), *Pteris* 29, 58, and 87 (Kurita 1967; Mitui 1968) were reported among respective species. Ferns are propagated by division, spores, or tissue culture.

Hybridization of different fern taxa may occur naturally. For example, *Asplenium trichomanes* subsp. *quadrivalens* is likely derived from taxa identical or close to *Asplenium trichomanes* subsp. *trichomanes* and *A. trichomanes* subsp. *inexpectans* (Vogel 1995). Some early breeding activities in ferns included a staghorn fern hybrid (*Platycerium* 'Cass' hybrid) developed by combining spores of *P. grande*, *P. alcicorne*, *P. stemaria*, and *P. hillii*. One intergeneric and several interspecific hybrids involving *Asplenium* exist; these are *A. sollerense* (*A. majoricum* × *A. petrarchae*), *A. orelli* (*A. majoricum* × *A. trichomanes* subsp. *quadrivalens*), *A. litardierei* (*A. petrarchae* subsp. *petrarchae* × *A. trichomanes* subsp. *inexpectans*), *A. lessinese* (*A. fissum* × *A. viride*), and *Asplenoceterach barrancense* (*Asplenium majoricum* × *Ceterach orricinarum*) (Wilfret and Sheehan 1981).

Boston fern (*Nephrolepis exaltata* var. Bostoniensis) was the first foliage plant to be commercially propagated in vitro (Hartman and Zettler 1986). Since then, fern cultivar development has largely relied on selection of somaclonal variants from tissue culture. For example, more than 30 Boston fern cultivars are produced in Florida, most of which originated as somaclonal mutants from tissue culture. Some cultivars have also originated as sports. Collectively, fern cultivars used as foliage plants increased from 10 in 1975 to 54 in 1998–1999 in Florida (Table 6.3). *Ceratopteris richardii*, or C-Fern, has been used extensively as a model system for studying gametophyte development (Banks 1999). Methods used for selection of mutants in the C-Fern could be suitable for developing other new fern cultivars.

F. *Ficus* (Moraceae)

The genus *Ficus*, the Latin name of fig, encompasses more than 800 species. Figs are woody trees, shrubs, or vines native to Asia, Africa, Aus-

tralia, and Central and South America (Huxley 1994). *Ficus* species are either monoecious or dioecious with a chromosome number of $2n = 26$ (Condit 1969). Each fig species is exclusively pollinated by a unique agaonid wasp (Agaonidae) species, whose offspring feed only on the tissue of the characteristic fig fruits. Recent mtDNA studies suggest that the fig-agaonid interaction might play an important role in fig species diversification (Cook and Lopez-Vaamonde 2001; Nason et al. 1998). Cultivated species are either produced for edible fruit or possess ornamental value.

Fig species grown as foliage plants initially include *F. benjamina*, *F. elastica*, *F. lyrata*, and *F. retusa*, but several new fig species have been introduced in recent years. *Ficus binnedijkii* 'Alii', which means "king" in Hawaiian, was introduced to the U.S. continent in the late 1980s. *Ficus microcarpa* originates from southeast Asia and is a giant tree in its native habitat and invasive in some introduced regions, but is cultivated as a miniature bonsai-like plant. *Ficus pumila*, a vine-type fig native to southeast Asia grown in hanging baskets, was introduced in the early 1980s. *Ficus salicifolia*, the willow leaf fig, originates from Indonesia and was introduced in the late 1990s.

Documented breeding activities on figs have only been reported on *F. carica*, a fruit tree fig (Storey 1975). There are no known breeding programs devoted to improvement of *Ficus* for use as foliage plants. New fig cultivars mainly come from the selection of sports from mutations or somaclonal variants. For example, *F. benjamina* 'Monique' and 'Wiandi' were sports of 'Exotica' and 'Natasha', respectively, and were selected by Huub van Diemer in Holland. *Ficus benjamina* 'Indigo' and 'Midnight' were sports of *F. benjamina* 'Exotica', selected by Jan van Geest in Holland. These new cultivars were introduced to the United States by Miami Agri-Starts, Inc., Homestead, Florida. Additional new *Ficus* cultivars include *F. benjamina* 'Midnight Princess' and 'Too Little'; *F. binnendijkii* 'Alii', 'Amstel King'; and *F. elastica* 'Cabernet', 'Sylvie', and 'Melany'. These new cultivars are not only esthetically appealing but also perform much better in interior low-light environments than *F. benjamina* 'Common' (Chen et al. 2001c). In 1975, two *F. benjamina*, four *F. elastica*, one *F. lyrata*, and one *F. retusa* cultivars were in the Florida foliage plant trade. Currently, cultivars of *F. benjamina*, *F. elastica*, *F. lyrata*, and *F. retusa* number fourteen, five, four, and two, respectively.

G. *Hedera* (Araliaceae)

The genus *Hedera*, commonly called ivy, is native to Europe, northern Africa, and western Asia (Huxley 1994). As stressed previously, English ivy (*H. helix*) is probably the most significant species native to temperate climate (Rose 1996) and used extensively as a foliage plant by

commercial growers worldwide. Algerian ivy (*H. canariensis*) is a distant second. Two noticeable characteristics of ivy are its evergreen leaves and the fact that it develops both juvenile and adult foliage. The juvenile leaves, those borne by the plant in its creeping or early climbing stages, are usually three to five lobed in *H. helix*. The adult leaves are produced on stiff, nonclimbing and rootless stems and are usually elliptic-lanceolate and not lobed. Flowers are produced on globose umbels, sometimes solitary but usually in compound panicles, each umbel carrying 10–15 flowers. Pollination is accomplished by flies, wasps, and bees (Rose 1996). *Hedera helix*, *H. azorica*, *H. maroccana*, *H. nepalensis*, and *H. rhombea* are diploid species with the chromosome number of $2n = 48$; *H. canariensis* var. *algeriensis* and *H. hibernica* are tetraploid, $2n = 96$ (Rose 1996).

Hedera helix in the foliage plant industry is grown primarily for its juvenile leaves, which are variegated or have different shapes. According to the American Ivy Society (Naples, Florida), ivy leaf shapes can be classified into nine categories in reference to the Pierot System (Pierot 1974): variegated (V), bird's foot (BF), fan (F), curlies (C), heart-shapes (H), miniature (M), ivy-ivies (I), adult (A), and oddities (O) (www.ivy.org). Plants with different leaf shape and variegation patterns, if stable in propagation, could potentially become new cultivars. The American Ivy Society is the International Registration Authority for new ivy cultivar registration. English ivy is propagated by cutting; tissue culture has not been used commercially. Rose (1996) listed more than 200 cultivars of *H. helix* varying in leaf sizes, shapes, colors, and variegation patterns; all were selected from sports. More than 40 cultivars of English ivy are grown in Florida.

H. Palms (Arecaceae)

Palms are woody monocotyledons, consisting of 200 genera and about 2,600 species (Jones 1995) and mainly distributed throughout subtropical and tropical regions of the world (Huxley 1994). Palms produce unisexual or bisexual flowers on one plant or on separate plants. Most palms flower regularly each year, and the transference of pollen from the stamens to the stigma is via insect vectors (beetles or small bees). Palms can be propagated sexually from seed or asexually by division or tissue culture.

Palms are excellent decoration plants for both indoor and outdoor environments. The genera that have been used for interior plantscaping include *Chamaedorea*, *Chrysalidocarpus*, *Howea*, *Phoenix*, and *Rhapis*. *Chamaedorea*, commonly known as parlor or bamboo palm, is native to Central and South America. At least eight species (*C. cataractarum*, *C.*

elegans, *C. erumpens*, *C. geonomiformis*, *C. metallica*, *C. microspadix*, *C. seifrizii*, and *C. tepejilote*) are currently used as foliage plants for interiorscaping. *Chrysalidocarpus lutescens*, also called areca palm, is native to Madagascar and is the most widely grown palm for foliage use. *Howea* is from Lord Howe Island, off the eastern coast of Australia. *Howea forsterana* is the species in the foliage plant trade. *Phoenix* was the ancient Greek name for the date palm. It is native to Africa and Asia, with two species, *P. roebelenii* and *P. reclinata*, used mostly as interior foliage plants. *Rhapis* (Lady palm) has been cultivated since the 1600s. Lady palms are distributed naturally mainly in China, Laos, Vietnam, and Thailand. *Rhapis excelsa* is the principal species grown in Florida, whereas *R. humilis* is more commonly grown in cooler climates. All the aforementioned palm species bear seeds at maturity except for *Rhapis humilis*, which rarely produces seed. Palm flowers are relatively large and easy to handle for breeding purposes. The number of palm cultivars produced in Florida remains relatively constant at around 20.

Extensive research has been conducted on the oil palm (*Elaeis guineensis*), and significant progress has been made on cultivar development (Soh et al. 2003). These include the use of molecular markers to determine genetic diversity (Barcelos et al. 1998; Mayes et al. 2000), development of inbred lines, test of combining ability, production of interspecific hybrids, introduction of palm germplasm for improving disease resistance and other agronomic traits, tissue culture, embryogenesis, microspore, and anther culture to generate haploid or double haploid plants (Breure and Verdooren 1995; Chavez and Sterling 1991; Richardson 1995). These methods suggest potential avenues for research in breeding new palm cultivars for use as foliage plants.

VI. FUTURE PROSPECTS

The wholesale value of foliage plants in the United States rose from $13 million in 1949 to $585 million in 2001 (Smith 1980; USDA 2002). As discussed above, cultivar development has played an important role in the steady growth of the foliage plant industry. New cultivar releases and new plant introduction provide products for new uses, thus increasing production. The future of the industry is bright because interiorscape with foliage plants has become an integral part of contemporary design in daily life. With increasing desire by consumers for novelty and new uses of living specimens in interior decoration, more new foliage plants and new cultivars should be developed and released. To meet the upcoming challenges, the following issues may need to be considered:

A. Germplasm Collection and Conservation

Foliage plants are important members of tropical and subtropical ecosystems; their collections should follow the provisions of the Convention on Biological Diversity at Rio de Janeiro (Anon. 1992). Germplasm of foliage plants are primarily maintained by plant collectors and botanical gardens. It would be very beneficial to breeders and researchers if the Ornamental Plant Germplasm Center (OPGC) would become actively involved in foliage plant conservation and provide researchers and breeders with convenient access. In addition, the term "foliage plant" refers to a very diverse group of plant genera, many of which have not been the subjects of detailed botanical research. Developing uniform standards for foliage plant evaluation regarding taxonomy, cytology, fertility, and crossability, as well as standardized procedures in plant introduction, are needed.

B. Breeding

Interspecific hybridization has been and will still be an important method of new cultivar development. However, other breeding methods in foliage plants should be considered. Some possibilities would include utilization of hybrid vigor obtained from crossing homozygous lines produced through in vitro culture of anther or ovaries, and population improvement by recurrent selection. Induced mutation using either physical or chemical agents for foliage plant cultivar development should be exploited, since many other ornamental plant cultivars are derived from this method (Langton 1987). Additionally, there are almost no breeding activities in many important foliage plant genera such as *Dracaena*, *Ficus*, *Hedera*, and various ornamental palms.

C. Somaclonal Variant Selection

The evidence that a large number of foliage plant cultivars are selected from somaclonal variants is probably the best example of how this new source of genetic variation is used in cultivar development. Research is needed to document the causes and frequencies of somaclonal variant occurrence using different explants and to develop procedures for generating the variants in different species. With more foliage plants becoming tissue-cultured, more cultivars will be selected from somaclonal variants. It has been reported that variant occurrence frequency can be accelerated when explants or calli are treated by mutagenic agents

(Maliga et al. 1981; van Harten 1998). It should be possible to increase variant occurrence frequency by introducing mutagenic compounds into culture media.

D. Transgene Technology

As stressed earlier, transgene technology could be particularly promising in foliage plant cultivar development since most foliage plants can be regenerated in tissue culture. It is possible that genes proven to be economically significant in improving agronomic crop traits after being transformed can be directly used for cultivar improvement in foliage plants. McCown (1997) listed several genes for improving plant forms. The expression of *iaaM* and *iaaH* for overproduction of indole-3-acetic acid (IAA) could lead to the increase of apical dominance with short internodes and small narrow leaves. On the other hand, transformation of *iaaL* gene could reduce the level of endogenous free IAA; as a result, more basal shoots could be formed, giving a dwarf and compact appearance. Isopentenyl transferase (*ipt*) gene transformation has been shown to reduce apical dominance, increase basal shoots, and more importantly, increase chlorophyll content and delay leaf senescence. Flower shapes and colors are important traits to *Anthurium*, *Aphelandra*, bromeliads, and *Spathiphyllum*. With the increased understanding of flower development and biochemistry of pigment biosynthesis, transgene technology may become an important tool to manipulate shapes and colors of these foliage plants' flowers. Transgene technology should be equally useful for engineering foliage plants in resistance to diseases and insects in both production and interiorscape.

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