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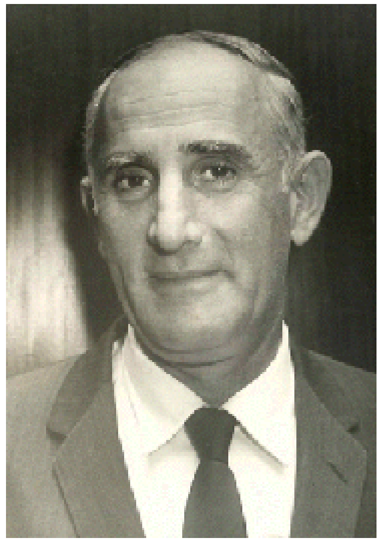

Pinhas Spiegel-Roy

Dedication: Pinhas Spiegel-Roy

This volume is dedicated to Dr. Pinhas Spiegel-Roy, Professor of Horticulture, in appreciation of his outstanding achievements in the genetics of fruit trees and the breeding of prime quality fruit tree cultivars. His novel citrus, table grapes, and almond cultivars, in particular, play currently an immense role in the Israeli and international fruit tree industry.

Pinhas was born in Mukachevo, Czechoslovakia in 1922 and graduated from high school with distinction. At the age of 18, in the midst of World War II (1940), he managed to immigrate to Israel (then Palestine) with a group of youth. In 1942 he attempted to enroll for Chemistry at the Hebrew University of Jerusalem but was not admitted, so he turned to Agriculture. His studies were interrupted by the 1948 Israeli War of Independence, in which he was injured. Soon afterward he joined the Department of Horticulture in the Israeli Government Experiment Station, now the Agricultural Research Organization (ARO) and completed his Ph.D. at the Hebrew University of Jerusalem in 1954. In 1959 he came to the United States for a series of scientific visits at the University of California, Davis, and other leading agricultural institutions. This visit focused his interest on the genetics of fruit trees and paved the way for his major breeding research. Dr. Spiegel-Roy held a series of administrative positions, serving as Deputy Head of the Volcani Center (1966–1969) and Director of the ARO Institute of Horticulture (1969–1975). In 1969 he established the Fruit Crop Breeding Department in the ARO and served as its Head until his retirement in 1989.

Dr. Spiegel-Roy engaged in a broad array of international activities. He organized and chaired the 18th International Horticultural Congress (Tel Aviv, 1970) and served as Honorary President of the International Society for Horticultural Science (1966–1970). Spiegel-Roy served as a Professor of Horticulture at the Hebrew University of Jerusalem and lectured also at the Technion, Israel Institute of Technology. He published over 100 articles in scientific journals and numerous notes and book chapters in local Israeli publications (in Hebrew). His *Biology of Citrus* (with E.E. Goldschmidt, Cambridge University Press, 1996) became an acknowledged citrus textbook worldwide. Dr. Spiegel-Roy's intellectual breadth and biotechnological breeding expertise made him a preferred invited speaker in international scientific conferences and symposia. When he attended a meeting, there was usually no need for an interpreter, since he mastered a large number of languages.

Although the foundations of the Israeli fruit tree introduction and breeding research approaches already existed, Dr. Spiegel-Roy may be righteously regarded as the initiator of modern fruit tree breeding research in Israel. He foresaw the future needs of the Israeli fruit industry and combined biotechnological approaches with classical breeding methods in an attempt to obtain new, productive, high-quality cultivars. The genetics of fruit trees self-incompatibility, parthenocarpy, and seedlessness were subject to penetrating research. Dr. Spiegel-Roy's broad horizons were revealed in a 1975, now classical, study of the origins and domestication of Old World fruit trees. He also identified the chimeral nature of ‘Shamouti’, the original Israeli ‘Jaffa’ orange.

Dr. Spiegel-Roy's seminal contribution to the breeding of table grapes deserves special attention. The importance of seedless grapes became evident at the beginning of the 1980s. Market demands for seedlessness grew constantly, and grape breeders worldwide tried to develop technologies to achieve this goal. Until that time breeders of grapes were able to cross only two seeded parents or a seeded maternal parent and a seedless paternal pollen donor. Using either of these combinations resulted in up to 80% of seeded F_1 offspring among the progeny, thus rendering the development of truly seedless cultivar almost impossible. The hybridization of two seedless parents was impossible as an embryo rescue technology was not available to the grape breeders worldwide. His pioneering research (Spiegel-Roy, P., N. Sahar, J. Baron, and U. Lavi. 1985. *In vitro* culture and plant formation from grape cultivars with abortive ovules and seeds. *J. Am. Soc. Hortic. Sci.* 110:109–112) paved the way to the establishment of an *in vitro*, in-ovule embryo rescue procedure. This newly discovered technology enabled the use of both seedless maternal and paternal lines in a specific cross followed by embryo rescue. Even today, after several decades of scientific and practical scrutiny, this protocol is considered highly efficient, synchronous, and nonlaborious, enabling production of thousands of F_1 grape plantlets annually. Numerous patented international cultivars were developed using this technology, including ‘Prime’, ‘Mystery’, ‘Rocky’, ‘Black Glory’, and ‘Big Pearl’. Dr. Spiegel-Roy's initial table grapes breeding program has been further developed and extended and is currently led by his former student Dr. Avichai Perl.

One of Dr. Spiegel-Roy's special talents was his ability to identify the needs and foresee the future prospects of every fruit crop. He understood that increasing yield and fruit quality are crucial for the developing almond industry and devised useful approaches to achieve these goals. Breeding for efficient pollinators that will cover the entire flowering season of the main Israeli cultivar ‘Um El Fahem’ and will be genetically compatible with its self-incompatibility genes was one major project. Another line of research consisted of breeding for new, self-compatible cultivars with high yield and large tasty kernel that do not require pollinator cultivars. Both of these activities have resulted in the establishment of several new cultivars and pollinators that constitute today the modern almond orchard in Israel. The array of self-compatible cultivars bred by Dr. Spiegel-Roy is currently used as a source for breeding new self-compatible cultivars that will eliminate the need for pollinators in the almond orchard altogether, and perhaps reduce the dependence on bees. All in all, Dr. Spiegel-Roy registered several novel almond cultivars, including ‘Gilad’, ‘Kochav’, ‘Kochva’, ‘Shefa’, and ‘Levad’; most of these cultivars are commercially grown in modern Israeli orchards. The almond breeding work is presently headed by Dr. Doron Holland.

Dr. Spiegel-Roy revolutionized the objectives of the Israeli citrus breeding research, identifying the production of seedless, easy-peeling mandarin cultivars as the major target for the future of the Israeli citrus industry. He developed a regenerative cell culture system, based on the natural regenerative potential of citrus nucellar cells. Further sophistication of the system enabled isolation, regeneration, and fusion of protoplasts, production of cybrids, plants from somatic fusion, and somaclonal variants. A peroxidase isozyme system was developed in order to distinguish between nucellar and zygotic seedlings of polyembryonic cultivars. A key role in this extensive research, as well as in the following breeding of new cultivars, was played by Dr. Spiegel-Roy's dedicated collaborator, Dr. Aliza Vardi, who also continued the project after his retirement. The breeding project is presently headed by Dr. Nir Carmi.

However, the real breakthrough in practical breeding of citrus cultivars did not emerge from the cell culture research, but rather from a combination of conventional breeding and irradiation-induced mutations. Although the initial idea of Dr. Spiegel-Roy was to irradiate cell cultures, irradiation of bud wood became the standard technique. Buds from old cultivars as well as newly released high-quality selections were irradiated with ^{60}Co, with the aim of inducing seedlessness. An efficient protocol for shortening of the juvenile period and rapid screening for parthenocarpic ability was developed. This focused effort resulted in a series of high-quality mandarin (*Citrus reticulata*) hybrid cultivar releases (15 patented cultivars), several of which reached commercialization and export. Of particular significance is the highly praised ‘Orri’ mandarin cultivar. ‘Orri’ was developed from a selection of plants grown from irradiated bud wood of ‘Orah’, a ‘Kinnow’ × ‘Temple’ hybrid. ‘Orri’ is currently the major citrus export cultivar of Israel and is already grown in Spain and South Africa.

Pinhas Spiegel-Roy is currently in his early nineties. He is remembered by all his colleagues and former students as a warm, kind, welcoming, bright, and highly inspiring person, very supportive and always ready to help. His broad vision and penetrating scientific research culminated in remarkable breeding achievements, which place him as a founder of the modern Israeli fruit industry and a leader of world horticulture.

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1
Ornamental Palms: Biology and Horticulture

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Abstract

Ornamental palms are important components of tropical, subtropical, and even warm temperate climate landscapes. In colder climates, they are important interiorscape plants and are often a focal point in malls, businesses, and other public areas. As arborescent monocots, palms have a unique morphology and this greatly influences their cultural requirements. Ornamental palms are overwhelmingly seed propagated, with seeds of most species germinating slowly and being intolerant of prolonged storage or cold temperatures. They generally do not have dormancy requirements, but do require high temperatures (30–35°C) for optimum germination. Palms are usually grown in containers prior to transplanting into a field nursery or landscape. Because of their adventitious root system, large field-grown specimen palms can easily be transplanted. In the landscape, palm health and quality are greatly affected by nutritional deficiencies, which can reduce their aesthetic value, growth rate, or even cause death. Palm life can also be shortened by a number of diseases or insect pests, some of which are lethal, have no controls, or have wide host ranges. With the increasing use of palms in the landscape, pathogens and insect pests have moved with the palms, both between and within countries, with some having spread virtually worldwide.

KEYWORDS: Arecaceae; insect pests; nursery production; nutrient deficiencies; plant diseases; propagation; transplanting

I. Introduction

Palms comprise a natural and distinctive, yet unusually diverse group of mostly tropical plants. The family includes ~2,500 species in 184 genera and is most diverse and rich in tropical Asia, the western Pacific, Central and South America, Australia, and Madagascar (Dransfield et al. 2005, 2008; Govaerts 2013). Where palms occur naturally, they are typically among the most economically important plants, providing food, beverages, and cooking oil; fiber for clothing, rope, baskets, mats, hats, and other uses; material for furniture and construction; and medicine and narcotics (Balick 1988; Balick and Beck

1990). Several palms have been domesticated and are of international economic importance, including *Phoenix dactylifera* (date palm), *Bactris gasipaes* (peach palm), *Cocos nucifera* (coconut palm), and *Elaeis guineensis* (African oil palm). The latter two are considered two of the world's ten most important agronomic crops (Janick and Paull 2008).

Palms are also important as ornamentals and are widely used in the landscape in tropical, subtropical, and Mediterranean climates around the world (Table 1.1, Plate 1.1). They are often the featured plants in botanical glasshouses in temperate climates. Indeed, they are the quintessential plant of the tropics and few, if any other, plants can capture that tropical motif as do the palms (Ledin 1961). *C. nucifera* in Hawaii and south Florida and *Phoenix canariensis* (Canary Island date palm) and *Washingtonia robusta* (Mexican fan palm) in California are the iconic or signature trees of these respective regions, filling the skyline and providing the tropical ambience upon which these tourism-reliant regions depend to draw visitors to support their economies.

Table 1.1 Common ornamental palms, along with their botanical and common names and information about their habit, size, uses, and environmental adaptations.

						Fruit	
Botanical name (synonyms)	**Common name**	**Habit/trunk diameter (cm)**	**Size (*h* × *w*) (m)**[z]	**Leaf type and length (m)**[y]	**Inflorescence length (m)**	**Length (cm)**	**Colo**
Acoelorrhaphe wrightii (Paurotis wrightii)	Everglades palm	Clustered/10	7 × 6	Palmate, 1	1	0.3	Orang brow
Acrocomia aculeata (A. media, A. mexicana, A. totai)	Gru–gru palm, macaw palm	Solitary/30	12 × 4	Pinnate, 2	1.5	2	Brow
Adonidia merrillii (Veitchia merrillii)	Christmas palm, Manila Palm	Solitary/15	4 × 2	Pinnate, 1	0.5	2.5	Red
Archontophoenix alexandrae	Alexandra palm	Solitary/20	14 × 4	Pinnate, 2	0.75	1	Red
A. cunninghamiana	King palm	Solitary/20	14 × 4	Pinnate, 2	0.75	1	Red
Areca catechu	Betel nut palm	Solitary/12	10 × 2.5	Pinnate, 1.3	0.60	5	Yellov orang
A. triandra aliceae	NCN[u]	Clustered/8	8 × 3	Pinnate, 1.5	0.30	2	Red
Arenga engleri	Formosa palm	Clustered/15	2.5 × 5	Pinnate, 2	0.75	2	Purpl red
A. pinnata	Sugar palm	Solitary/45	15 × 6	Pinnate, 3	2.25	6	Yellov
Astrocaryum mexicanum	NCN	Solitary/10	5 × 3	Pinnate, 1.5	0.75	5	Brow
Bismarckia nobilis	Bismarck palm	Solitary/40	10 × 5	Palmate, 2.5	2.25	5	Brow
Brahea armata	Mexican blue palm	Solitary/30	8 × 3	Palmate, 1.5	5	2.5	Black
B. edulis	Guadalupe palm	Solitary/=30	8 × 3	Palmate, 1.5	2	2.5	Black
Butia odorata (B. capitata)	Pindo palm, jelly palm	Solitary/40	5 × 3	Pinnate, 1.5	1	2.5	Yellov orang
Carpentaria acuminata	NCN	Solitary/20	15 × 3	Pinnate, 1.5	1	1.5	Red

						Fruit	
Botanical name (synonyms)	**Common name**	**Habit/trunk diameter (cm)**	**Size (*h* × *w*) (m)**[z]	**Leaf type and length (m)**[y]	**Inflorescence length (m)**	**Length (cm)**	**Colo**
Caryota maxima	Fishtail palm	Solitary/30	15 × 4	Pinnate, 2	3	2.5	Reddi
C. mitis	Clustered fishtail palm	Clustered/12	10 × 4	Pinnate, 2	1.5	1.2	Black
Chamaedorea benziei	NCN	Solitary/4	3 × 1.5	Pinnate, 0.7	1	1	Black
C. cataractarum	Cat palm	Clustered/3	1 × 3	Pinnate, 1	0.75	1	Black
C. elegans	Parlor palm	Solitary/1.5	2 × 0.8	Pinnate, 0.4	1	0.7	Black
C. hooperiana	Maya palm	Clustered/3	3 × 3	Pinnate, 1.5	0.75	1	Black
C. metallica	NCN	Solitary/1.5	1 × 0.4	Bifid to pinnate, 0.2	0.25	1.2	Black
C. microspadix	Bamboo palm	Clustered/1	3 × 2	Pinnate, 0.3	0.25	1.2	Red-orang
C. plumosa	NCN	Solitary/3	3 × 1.5	Pinnate, 1	0.75	1	Black
C. radicalis	NCN	Solitary/2.5	1 × 1	Pinnate, 0.6	1.25	1.2	Red
C. seifrizii (C. erumpens)	Bamboo palm	Clustered/1.5	2.5 × 1	Pinnate, 0.3	0.20	0.8	Black
Chambeyronia macrocarpa	NCN	Solitary/12	8 × 3	Pinnate, 1.5	1	4.5	Red
Coccothrinax argentata	Thatch palm	Solitary10	8 × 2	Palmate, 1	0.5	1.2	Black
C. crinita	Old-man palm	Solitary/12	5 × 2	Palmate, 1	1.5	2.5	Pinkis
Cocos nucifera	Coconut palm	Solitary/45	20 × 6	Pinnate, 3	1.25	30	Gree yello

						Fruit	
Botanical name (synonyms)	**Common name**	**Habit/trunk diameter (cm)**	**Size (*h* × *w*) (m)**[z]	**Leaf type and length (m)**[y]	**Inflorescence length (m)**	**Length (cm)**	**Color**
Cyrtostachys renda	Sealing wax palm	Clustered/8	8 × × 3	Pinnate, 1	0.9	1	Black
Dictyosperma album	Princess palm	Solitary/15	14 × 3	Pinnate, 1.5	0.6	1.2	Black
Dypsis cabadae	Cabada palm	Clustered/10	8 × 5	Pinnate, 1.5	1.25	1.2	Red
D. decaryi	Triangle palm	Solitary/30	4 × 3	Pinnate 1.5	1.25	2.5	Green yellow
D. leptocheilos	Teddy bear palm	Solitary/20	10 × 4	Pinnate, 2	1.5	1.2	Brown
D. lutescens (Chrysalidocarpus lutescens)	Areca palm	Clustered/10	10 × 5	Pinnate, 1.5	1.25	2.5	Yellow black
Euterpe oleracea	Assai palm	Clustered/20	15 × 5	Pinnate, 2	1	2	Black
Heterospathe elata	Sagisi palm	Solitary/20	15 × 4	Pinnate, 2	1.25	1	White
Howea forsteriana	Kentia palm, sentry palm	Solitary/20	15 × 4	Pinnate, 2	0.6	4	Red
Hyophorbe lagenicaulis (Mascarena lagenicaulis)	Bottle palm	Solitary/60	6 × 3	Pinnate, 1.5	0.9	2.5	Black
H. verschaffeltii (*Mascarena verschaffeltii*)	Spindle palm	Solitary/30	8 × 4	Pinnate, 2	0.7	2	Black
Jubaea chilensis (J. spectabilis)	Chilean wine palm	Solitary/200	25 × 8	Pinnate, 4	1.25	4	Yellow orange
Latania loddigesii	Blue latan palm	Solitary/25	7 × 4	Palmate, 2	2	8	Green brown
Licuala grandis	NCN	Solitary/8	3 × 3	Palmate, 1.5	2	1.2	Red
L. spinosa	NCN	Clustered/5	6 × 3	Palmate, 1	2.5	1.2	Red
Livistona australis	Australian fan palm	Solitary/30	20 × 5	Palmate, 2/5	1.25	2	Black

						Fruit	
Botanical name (synonyms)	**Common name**	**Habit/trunk diameter (cm)**	**Size (*h* × *w*) (m)[z]**	**Leaf type and length (m)[y]**	**Inflorescence length (m)**	**Length (cm)**	**Colo**
L. chinensis	Chinese fan palm	Solitary/30	20 × 6	Palmate, 2.5	2	2.5	Bluisl greer
L. decora (L. decipiens)	Ribbon fan palm	Solitary/25	15 × 6	Palmate, 2.5	3	1.5	Black
Phoenix canariensis	Canary Island date palm	Solitary/100	20 × 8	Pinnate, 4	2	1.2	Golde orang
P. dactylifera	Date palm	Clustered or solitary/45	20 × 8	Pinnate, 3.5	2.5	2.5	Dark browı black
P. reclinata	Senegal date palm	Clustered/20	15 × × 15	Pinnate, 3	1	2	Black
P. roebelenii	Pygmy date palm	Solitary/10	4 × 2.5	Pinnate, 1.2	0.6	1	Black
P. sylvestris	Wild date palm	Solitary/45	15 × 6	Pinnate, 3	1	2.5	Purpl
Ptychosperma elegans	Solitaire palm	Solitary/10	10 × 3	Pinnate, 1.5	0.75	1.2	Red
P. macarthurii	Macarthur palm	Clustered/6	10 × 5	Pinnate, 1.5	0.75	1.2	Red
Ravenea rivularis	Majesty palm	Solitary/45	15 × 3	Pinnate, 1.5	1	1.2	Red
Rhapis excelsa	Lady palm	Clustered/3	4 × 4	Palmate, 0.7	0.3	0.8	White
R. humilis	Slender lady palm	Clustered/3	5 × 5	Palmate, 0.7	0.3	0.8	White
Roystonea regia	Royal palm	Solitary/50	25 × 8	Pinnate, 4-5	0.3	0.6	Redd purpl
Sabal Mexicana	Texas palmetto	Solitary/30	20 × 5	Palmate, 2.5	2	1.2	Black
Sabal minor	Dwarf palmetto	Solitary/15	2.5 × 3	Palmate, 2	3	0.8	Black
S. palmetto	Palmetto palm, cabbage palm	Solitary/40	20 × 4	Palmate, 2-2.5	2.5	1.2	Black

						Fruit	
Botanical name (synonyms)	**Common name**	**Habit/trunk diameter (cm)**	**Size (*h* × *w*) (m)[z]**	**Leaf type and length (m)[y]**	**Inflorescence length (m)**	**Length (cm)**	**Colo**
Saribus rotundifolius (L. rotundifolia)	Footstool palm	Solitary/25	20 × 5	Palmate, 2	2.5	2.5	Oran red
Syagrus romanzoffiana	Queen palm	Solitary/25	20 × 6	Pinnate, 3-3.5	2.5	2.5	Yello oranc
Thrinax radiata	Thatch palm	Solitary/12	12 × 4	Palmate, 2	1	0.6	White
Trachycarpus fortunei	Windmill palm, Chinese windmill palm	Solitary/12	7 × 3	Palmate, 1	0.5	1.2	Bluisl
T. wagnerianus	Windmill palm	Solitary/12	7 × 2	Palmate, 1	0.5	1.2	bluisl
Veitchia arecina (*V. montgomeryana*)	Montgomery palm, NCN	Solitary/20	20 × 5	Pinnate, 2.5	1.25	4	Red
V. joannis	NCN	Solitary/40	30 × 6	Pinnate, 3	1	5	Red
Veitchia winin	NCN	Solitary/30	25 × 5	Pinnate, 2.5	1.25	1	Red
Washingtonia filifera	California fan palm	Solitary/100	20 × 6	Palmate, 2.5	5	0.6	Black
W. robusta	Mexican fan palm	Solitary/50	30 × 5	Palmate, 2.5	4	0.6	Black
Wodyetia bifurcata	Foxtail palm	Solitary/25	10 × 5	Pinnate, 2.5	3	5	Red

The categories covering habit, size, uses, and environmental adaptation are annotated and described or defined at the en mostly from Meerow (2006), Riffle et al. (2012), and Hodel (2012).

[z]Height and width are averages for typical landscape specimens; width is through canopy of solitary species or through c

[y]Length includes leaf blade and petiole but not leaf base.

[x]BG: Background: taller and/or wider plants that can interrupt a line of sight or in front of which smaller plants can be pc slow-growing plants that do not block a line of sight and that can be positioned in front of larger plants; B: border—short area or for an area along a building or other structure or lining a street; H: hedge screen—typically densely clustered pla block a view; M: mass—mostly very small, dwarf, and/or trunkless plants that can be planted canopy to canopy to create a specimen—a plant that can stand alone on its own merits; C: container—typically a small or slow-growing plant that can r attaining or nearly attaining maturity, note that nearly all palms make suitable container subjects when young and that re for palms that are especially distinctive or exhibit adult characters when still relatively small plants; I: indoors—a plant tc encountered inside homes, offices, and other buildings where light and humidity are usually low.

[w]Shade: no direct sun; part sun: filtered sun or morning full sun and afternoon shade; sun: full sun all day.

						Fruit	
Botanical name (synonyms)	**Common name**	**Habit/trunk diameter (cm)**	**Size (*h* × *w*) (m)**[z]	**Leaf type and length (m)**[y]	**Inflorescence length (m)**	**Length (cm)**	**Color**

[v] USDA climate zone recommendations are based mostly on Meerow (2006) and Riffle et al. (2012).

[u] No common name.


(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)
(i)

Plate 1.1 Ornamental palms. (a) *Acoelorrhaphe wrightii* (paurotis palm) (b) *Adonidia merrillii* (Christmas palm); (c) *Bismarckia nobilis* (Bismarck palm); (d) *Chamaedorea cataractarum* (cat palm); (e) *Cocos nucifera* (coconut palm); (f) *Dypsis lutescen*s (areca palm); (g) *Livistona chinensis* (Chinese fan palm); (h) *Phoenix canariensis* (Canary Island date palm); (i) *P. dactylifer*a (date palm); (j) *P. roebelenii* (pygmy date palm); (k) *P. sylvestris* (wild date palm); (l) *Ptychosperma elegans* (solitaire palm); (m) *Roystonea regia* (royal palm); (n) *Sabal palmetto* (cabbage palm); (o) *Syagrus romanzoffian*a (queen palm); (p) *Veitchia* sp. (Montgomery palm); (q) *Washingtonia robusta* (Mexican fan palm); (r) *Wodyetia bifurcata* (foxtail palm) (See the color version of this plate in Color Plates Section).

In warmer parts of the United States, especially Hawaii, Florida, and California but also in Arizona, Texas, and the Gulf Coast, palms are a significant and increasing component of ornamental wholesale production nurseries. Palms of all sizes are grown for landscape use in these areas but also for indoor use everywhere. The monetary value of palm extends from the seed to transplantation of mature palms into residential and commercial landscapes. For the Florida nursery industry alone, the monetary value of palms has almost doubled every 5 years for the past 10 years. The estimated total sales value for palm trees by Florida producers in 2010 was $404 million, representing 9.5% of nursery growers' sales (Hodges et al. 2011). While this represents only a 2.5% increase in percentage of nursery sales from 2005, it is a near double of the monetary value ($220 million) from 2005 (Hodges and Haydu 2006). The 2005 monetary value was a near double of the 2000 palm sales, which were $123 million (Hodges and Haydu 2002). In

2010, the percentage of sales (9.5%) of palms was equal to the combination of deciduous shade trees, flowering and fruiting trees, and evergreen trees (9.8%).

Along with this increase in popularity has come an increased interest in how to grow, plant, and manage landscape palms. However, palms are unique among landscape plants and have several unusual features that set them apart from other woody plants and affect their nursery production and landscape management. These features include the lack of a cambium and ability for secondary growth in the stem; typically only one growing point or apical meristem per stem; an adventitious root system composed of nonwoody roots, with all primary- or first-order roots arising separately from one another at or near the base of the stem; and an aggregation of photosynthetic and reproductive efforts into relatively few but large organs (leaves and inflorescences) (Tomlinson 1990; Hodel 2012).

Those who grow or manage landscape palms frequently do not understand these unique features, and this lack of understanding often leads to mismanagement of palms in the nursery and landscape. Also, until recently, most of the information about production and management of landscape palms was anecdotal in nature and little research-based information was available (Broschat and Meerow 2000). Thus, the need for research-based information on how to grow, plant, and manage landscape palms is real and urgent. This publication reviews the literature on the biology, production, planting and transplanting, nutrition, irrigation, pruning, interiorscape use, disorders, and pest and diseases of ornamental palms.

II. Palm Biology

A. What Is Palm?

Palms are unique among landscape plants and have several features that set them apart from other woody plants. Although until recently divided into two major groups, flowering plants (angiosperms) are now divided into three major groups: basal or primitive angiosperms (*Magnolia*, *Liriodendron*, etc.), monocotyledons (monocots), and eudicotyledons (eudicots). Monocots are distinguished from basal angiosperms and eudicots by having one cotyledon (seed leaf) rather than two, flower parts (sepals, petals, carpels, etc.) in threes or multiples of threes rather than in fours or fives, parallel rather than net leaf venation, and vascular bundles (phloem and xylem) dispersed throughout the stem rather than in two concentric rings with a cylindrical cambium between them. Palms are woody monocots, although they do not form wood in the same manner or have the same type of wood as other types of trees. A combination of characters distinguishes palms from all other monocots, including a woody stem, monopodial growth habit, petiolate leaves with initially closed bases, the mode of leaf initiation and development (plication and later splitting into segments that arise from a prominent midrib, an inflorescence (flower stalk) that is always initially enclosed within a two-edged bract (modified leaf), one ovule per carpel, and relatively large seeds (Dransfield et al. 2008). Sago palms (*Cycas* spp., coniferous plants), ponytail palms (*Nolina* spp.), traveler's palm (*Ravenala madagascariensis*), and other palm-like plants (dracaenas, yuccas) are not palms, although they have a palm-like habit and are commonly referred to as palms.

B. Taxonomy and Distribution

Being a natural and well-defined group, taxonomists have placed palms in their own order, Arecales (formerly Principes), composed of one family, Arecaceae or Palmae. The palm family is divided into five subfamilies based on DNA sequence data and morphological characters: Arecoideae, Calamoideae, Ceroxyloideae, Coryphoideae, and Nypoideae (Dransfield et al. 2005, 2008). The commonly cultivated genera of landscape palms in the United States occur in the Arecoideae and Coryphoideae subfamilies. These include

Archontophoenix, *Butia*, *Chamaedorea*, *Cocos*, *Dypsis*, *Howea*, *Ptychosperma*, *Roystonea*, *Syagrus*, *Veitchia*, and *Wodyetia* of the Arecoideae and *Brahea*, *Bismarckia*, *Caryota*, *Chamaerops*, *Livistona*, *Phoenix*, *Pritchardia*, *Rhapis*, *Sabal*, *Trachycarpus*, and *Washingtonia* of the Coryphoideae.

Most species of palms naturally inhabit moist to wet tropical areas in Central and South America, Madagascar, Southeast Asia, Malaysia, Indonesia, Australia, and the western Pacific (Dransfield et al. 2005, 2008; Govaerts 2013). The cold intolerance across the entire family is the most limiting factor in where and how palms can be grown in the landscape. However, a small percentage of palms, ~5–10% of the species, originate in subtropical or even warm temperate regions and are much better adapted to cultivation in these or similar areas (Meerow 2005).

C. Growth and Development

Palms pass through several developmental growth phases from the embryo (seed) to reproductive adult, each of which has features that can affect their management in the nursery and landscape. Tomlinson (1990) identified five distinct phases, although the transition between each is smooth and continuous: (1) embryonic, (2) seedling, (3) establishment, (4) adult vegetative, and (5) adult reproductive. Nursery production managers deal mostly with palms in the embryonic, seedling, and establishment phases while landscape managers deal mostly with palms in the adult vegetative and reproductive phases, although there is some overlap, especially in the establishment and adult vegetative phases and especially in nurseries that field-grown palms.

The embryonic phase refers to the development of the embryo within the seed, from fertilization to germination (Tomlinson 1990). Critical morphological changes that occur during the seedling phase include emergence of the apical meristem and the production of the first scale (rudimentary) and bladed (“true”) leaves, radicle (first and rudimentary root), and haustorium (specialized growth structure of the cotyledon that grows into the endosperm to absorb carbohydrates for growth and development) (Tomlinson 1990).

The establishment phase covers the time from the seedling phase until the stem has attained its maximum diameter and begins to elongate vertically (Tomlinson 1990). During this phase, stems increase in diameter with little vertical elongation, vascular bundles increase in number and size, roots become more numerous and larger, and leaves transition from strap-like or bifid juvenile foliage to pinnate or palmate adult foliage. The canopy attains its maximum size and number of leaves at the end of the establishment phase, essentially “fixing” the transport capacity of the stem for future growth. Once the stem has attained its maximum diameter and elongates vertically, there will be no further increase in its diameter or in the number of vascular bundles, primarily because of the lack of a vascular cambium and subsequent secondary growth. Thus, the stem is “overbuilt” during this phase because it must be sufficiently developed and constructed to accommodate all future growth, including increases in stem height, mass, strength, and transport requirements (Tomlinson 1990, 2006).

The establishment phase can be lengthy, several years or more, and, because most of the growth occurs at or near ground level, there is little, visible upward growth, (Tomlinson 1990). For most palms the establishment phase occurs with the apical meristem close to the ground. However, in some palms the establishment phase occurs mostly below ground and involves a radical reorientation of the apical meristem so that stem growth is initially downward prior to growing upward to resume the more typical, erect habit (Tomlinson 1990). This type of growth, which typically makes the establishment phase much longer, results in an underground, saxophone-shaped stem, usually with a low, above-ground “heel.” This saxophone-shaped stem occurs in some species of several genera, including *Chamaedorea*, *Dypsis*, *Ravenea*, *Rhopalostylis*, and *Sabal* (Tomlinson 1990; Hodel 2012).