New Insights into Breeding and Propagating Magnolias©

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It is a fascinating time to be growing magnolias. Recent developments, including a refined understanding of the evolutionary relationships, availability of new germplasm, and a formidable group of plant breeders, propagators, and aficionados are synergizing a magnolia renaissance. These forces are leading to exciting new hybrids, improved production methods, and a resurgence of interest in magnolias.

SYSTEMATICS AND CYTOGENETICS

With the advent of molecular phylogeny, flow cytometry, and the continued reassessment of morphology and taxonomy of the subfamily Magnolioideae, the understanding of the evolution, genetics, and relationships among magnolia species has improved considerably (Azuma et al., 1999, 2001, 2004; Figlar, 2000, 2006; Figlar and Nooteboom, 2004; Kim et al., 2001; Kumar, 2006; Nie et al., 2008; Parris et al., 2010, Qiu et al., 1995). The now widely-accepted taxonomic treatment of this group has *Magnolia* as the sole genus in the subfamily Magnolioideae with former genera *Manglietiastrum*, *Manglietia*, *Michelia*, *Pachylarnax*, and *Parakmeria* embedded within sectional ranks. More specifically, the former genus *Michelia* is now placed within subgenus *Yulania*, section *Michelia.* The former genus *Manglietia* is now placed in subgenus *Magnolia*, section *Manglietia*. The former genera *Manglietiastrum*, *Parakmeria*, and *Pachylarnax* are now placed in subgenus *Gynopodium*, section *Gynopodium* (see Table 1 for an abbreviated classification with selected taxa. A more complete classification can be found at the Magnolia Society International website <http://www.magnoliasociety.org/Classification>. This reorganization is something of a revelation that has significant implications for breeding and propagation of magnolias.

The cytogenetics of magnolias is complicated with over 250 species that range in ploidy level from diploid to hexaploid. Research by Parris et al. (2010) provides detailed information on ploidy of over 300 species and cultivars of magnolias. This reference gives insights into reproductive biology, confirmation of numerous hybrids and induced polyploids, and provides a valuable database for magnolia breeders.

Implications for Breeding

Plant breeders typically want to combine desirable traits from different parents. Genetic diversity is the raw material at hand and the greater the available diversity, the greater the potential opportunities — within limits. Plant breeding is a genetic reunion of sorts, bringing together divergent linages, but if the lineages/species are too distinct, they will lack reproductive compatibility and genetic synteny and will either not hybridize or may hybridize and produce undesirable or sterile offspring. Thus, detailed information on the relatedness of different species provides insights into what plants may or may not hybridize. The reorganization of *Michelia*, *Manglietia*, and to a lesser extent *Parakmeria*, *Manglietiastrum*, *Pachylarnax* into specific subgenera and sections within the genus *Magnolia* provides valuable insight and direction for plant breeders. As a result of this new understanding, many new hybrids are being developed that have considerable potential to combine and enhance flower color, cold hardiness, fragrance, persistent foliage, and a range of mature sizes and habits (Table 2). Although best success is generally had breeding among magnolias of the same taxonomic section, magnolias will often hybridize if they are simply in the same subgenus. Crosses between magnolias in different subgenera are rare, though Bill Smith (pers. commun.) was successful in hybridizing *M. lotungensis* (subgenus *Gynopodium*) and *M. virginiana* (subgenus *Magnolia*).

Polyploidy is an important factor in plant breeding because it can influence reproductive compatibility, fertility, and expression of traits. The greatest success is generally had breeding among parents of the same ploidy. Interploid hybrids can often be produced, but fertility of the progeny may be greatly reduced. For example, *M. liliiflora* (4*x*) and *M. stellata* (2*x*) will hybridize, but produce mostly sterile triploids. Hybrids between *M. acuminata* (4*x*) and *M. denudata* (6*x*), *M. campbellii* (6*x*) and *M. liliiflora* (4*x*), *M. liliiflora* (4*x*) and *M. sprengeri* (6*x*), and *M. denudata* (6*x*) and *M. liliiflora* (4*x*), generally produce pentaploids with very low or no female fertility and limited male fertility. Crosses between *M. virginiana* (2*x*) and *M. grandiflora* (6*x*) and *M. sieboldii* (2*x*) and *M. grandiflora* (6*x*) have been successful and produced tetraploid progeny with limited fertility.

Table 1. Organization of selected *Magnolia* species, hybrids, and cultivars by current taxonomy and ploidy levels with informed speculation on candidate understocks for experimentation, particularly in the SE United States of America.

Classification	Ploidy	*Magnolia* scion taxa	Magnolia candidate understocks (other than own species)[1]
		Subgenus *Magnolia*	
Section *Magnolia*	2*x*	*guatamalensis*, *sharpie*, *virginiaina*	*virginiana* var. *australis* (may sucker some)
	6*x*	*grandiflora*, *tamaulipana*	*grandiflora*
Section *Gwillimia*	2*x*	*coco*, *delavayi*, *hodgsonii*, *liliifera*	Possibly *virginiana* var. *australis* (may sucker some)
Section *Rhytidospermum*	2*x*	*obovata* (*hypoleuca*), *officinalis*, *rostrata*, *tripetala*, *sieboldii*, ×*wieseneri* (*obovata* × *sieboldii*)	*tripetala* or *obovata*
Section *Manglietia*	2*x*	*aromatica, changhungtana, conifera*, *fordiana*, *garrettii*, *hookeri*, *insignis*, *kwangtungensis*, *ovoidea*, *yuyuanensis*, *insignis* × *yuyuanensis*	*yuyuanensis* (good cold hardiness) or possibly *virginiana* var. *australis* (may sucker some)
Section *Macrophylla*	2*x*	*macrophylla*	*tripetala* or *obovata*
Section *Auriculata*	2*x*	*fraseri*	*tripetala* or *obovata*
Section *Kmeria*	2*x*	*thailandica*	Possibly *virginiana* var. *australis* (may sucker some) or *tripetala*
Intersectional hybrids	2*x*	*insignis* × *sieboldii* *insignis* × *virginiana* e.g., 'Katie-O'; *obovata* × *virginiana* e.g., 'Nimbis'; *sieboldii* × *virginiana*; ×*thompsoniana* (*virginiana* × *tripetala*); *yuyuanensis* × *virginiana*	Possibly *tripetala* *virginiana* var. *australis* (may sucker some)
	4*x*	×*freemani* (*virginiana* × *grandiflora*) e.g., 'Maryland'; *sieboldii* × *grandiflora* e.g., 'Exotic Star'	*grandiflora*

Table 1. Continued.

Classification	Ploidy	*Magnolia* scion taxa	Magnolia candidate understocks (other than own species)[1]
		Subgenus *Yulania*	
Section *Yulania*	2*x*	*amoena*, *biondii*, *kobus*, *salicifolia*, *stellata*, *zenii*, salicifolia 'Wada's Memory'; ×*loebneri* (*kobus* ×*stellata*), e.g., 'Leonard Messel', 'Spring Snow'	*stellata*, *kobus*, ×*loebneri*, *stellata* × *liliiflora*
	3*x*	*stellata* × *liliiflora*, e.g., 'Ann', 'Betty' *acuminata* × *stellata*	×*loebneri, kobus*, *stellata* × *liliiflora* *acuminata*, ×*brooklynensis*
	4*x*	*acuminata*, *cylindrical*, *liliiflora*, ×*brooklynensis* (*acuminata* × *liliiflora*) e.g., 'Black Beauty', 'Judy Zuk', 'Solar Flair', 'Sunburst', 'Sunspire', 'Yellow Bird'	*acuminata*, ×*brooklynensis*, *cylindrica*, *kobus*, ×*loebneri*, ×*soulangeana*, 'Alexandrina', 'Galaxy', 'Heaven Scent', 'Rustica Rubra', 'Yellow Lantern'
	5*x*	*acuminata* × *denudata,* e.g., 'Butterflies', 'Elizabeth', 'Ivory Chalice', 'Legend', 'Sun Ray' *campbellii* × *liliiflora*, e.g., 'Star Wars', 'Vulcan' *liliiflora* × *sprengeri*, e.g. 'Galaxy', 'Spectrum' ×*soulangeana* (*denudata* × *liliiflora*)	*acuminata*, ×*soulangeana*, 'Alexandrina', 'Galaxy', 'Heaven Scent', 'Rustica Rubra', 'Yellow Lantern' ×*soulangeana*, 'Alexandrina', 'Rustica Rubra' ,'Galaxy', 'Heaven Scent' *sprengeri*, ×*soulangeana*, 'Galaxy' ×*soulangeana*, 'Alexandrina', 'Rustica Rubra'
	~5*x*-7*x*	Advanced generations of ×*soulangeana* and other related cultivars: 'Albatross', 'Black Tulip', 'Cleopatra', 'Daybreak', 'Frank's Masterpiece', 'Genie', 'Jon Jon' , 'March Till Frost', 'Paul Cook', 'Rose Marie', 'Tina Durio', 'Todd Gresham', 'Sayonara', 'Sunsation', 'Yellow Lantern'	×*soulangeana*, 'Alexandrina', 'Galaxy', 'Heaven Scent','Rustica Rubra', 'San Jose', 'Yellow Lantern'
	6*x*	*campbellii*, *dawsoniana*, *denudata*, *sargentiana, sprengeri*, *denudata* × *sprengeri*, *sargentiana* × *campbellii*, ×*veitchii* (*campbellii* × *denudata*)	*sprengeri*, 'San Jose', 'Galaxy', 'Heaven Scent'
Section *Michelia*	2*x*	*cavaleriei*, *champaca*, *chapensis*, *doltsopa*, *ernestii*, *figo*, *floribunda*, *foveolata*, *fulva*, *laevifolia*, *lanuginosa*, *maudiae*, *martinii*, *odora*, *shiluensis*, *sirindhorniae*, ×*alba* (=*champaca* × *montana*), ×*foggii* (=*figo* × *doltsopa*), *laevifolia* × *figo*	*foveolata* or *laevifolia.* Possibly *kobus*, *liliiflora*, *stellata*, *liliiflora* × *stellata*, ×*loebneri*

Table 1. Continued.

Classification	Ploidy	*Magnolia* scion taxa	Magnolia candidate understocks (other than own species)[1]
		Subgenus *Gynopodium*	
Section *Gynopodium*	6*x*	*lotungensis*, *yunnanensis*	Possibly *grandiflora*
Section *Manglietiastrum*	2*x*	*sinica*	Possibly *virginiana*

[1]Candidate understocks identified here may be more readily available or have better long-term compatibility, cold hardiness, regional or soil adaptability, disease resistance, or be suitable for hybrid scions than other alternatives. Note, candidate rootstocks may not be in the same taxonomic group or ploidy level as the scion.

Table 2. Partial list of reported interspecific hybrids among plants formally classified in the genus *Manglietia, Michelia*, and *Parakmeria* and now classified as *Magnolia* (adapted from Figlar, 2014).

Subgenus *Magnolia*
M. sieboldii × *M. insignis*
M. tripetala hyb. × *M. insignis*
M. grandiflora × *M. insignis*
M. insignis × *M. grandiflora*
M. insignis × *M. sapaensis*
M. sapaensis × *M. insignis*
M. changhungtana × *M. insignis*
M. insignis × *M. fraseri*
M. macrophylla subsp. *ashei* × *M. insignis*
M. yuyuanensis × *M. insignis*
M. yuyuanensis × *M. virginiana*
M. sieboldii × *M. yuyuanensis*
Subgenus *Yulania*
M. foveolata × *M. laevifolia*
M. laevifolia × *M. foveolata*
M. foveolata × *M. figo* var. *crassipes*
M. acuminata var. *subcordata* × *M. figo* var. *crassipes*
M. laevifolia × *M. maudiae*
M. laevifolia × *M. champaca*
M. stellata hyb. × *M. laevifolia*
M. stellata × *M. figo* var. *skinneriana*
Subgenus *Gynopodium* × Subgenus *Magnolia*
M. lotungensis × *M. virginiana*

IMPLICATIONS FOR PROPAGATION

Stem Cuttings

Although the capacity of magnolias to root from stem cuttings varies considerably among species and cultivars, many taxa can be readily propagated in this way. Conventional wisdom has indicated that deciduous magnolias are best rooted in the spring from softwood cuttings while evergreen taxa are generally rooted from semi-hardwood cuttings in the fall (Tubesing, 1998). However, this is not always the case. For example, rooting for *M. virginiana* var. *australis* 'Santa Rosa', a deciduous to semi-evergreen cultivar was optimized at 83% from November semi-hardwood cuttings treated with a 1-s dip of 5,000 ppm liquid IBA in 50% isopropanol (Griffin et al., 1999) while cuttings from *M. laevifolia* 'Michelle', an evergreen species, rooted from 88 to 96% from softwood cuttings take in early June with no significant effect of a 5-s dip of K-IBA in water ranging from 0 to 50,000 ppm (unpublished research, Gillooly and Ranney). These observations suggest that we may need to reevaluate our approaches and look more closely at timing and rooting windows including softwood cuttings for evergreen species, particularly in section *Michelia*. Might general cutting propagation protocols apply to taxonomic sections? Some propagators are also reporting good success treating certain magnolia cuttings with very high rates (10,000-50,000 ppm) of IBA (Ethan Guthrie, pers. commun.; Sharma et al., 2006) which deserves further study.

Grafting, Graft Compatibility, and Rootstock Selection

Although own-rooted plants produced from cuttings or micropropagation are often preferred and minimize issues with rootstock suckering, there can be advantages to grafting. Rootstocks can have a profound influence on growth of the scion and can potentially enhance adaptability to poor soils and resistance to diseases, insects, and nematodes (Garner, 1988; Hartmann et al., 2010; Macdonald, 1986; Ranney et al., 1991; Ranney and Bir, 1994; Ranney and Whitman II, 1995; Rom and Carlson, 1987). And, the difficulty of rooting some magnolia species and cultivars often makes grafting the next best option available to propagators.

Magnolias are generally considered to have broad graft compatibility (Treseder, 1978) to the point that scion/rootstock combination are often given little consideration and generic rootstocks (e.g., *M. kobus*) are used for a broad range of taxonomically distinct scions. Initial graft success can depend on many factors including the condition and handling of both the rootstock and scion, skill of the grafter, timing, environmental conditions, aftercare, production/propagation systems, etc., that may have greater initial importance than the genetic relatedness of the component parts. Although true short-term graft incompatibility is rarely observed in magnolias (at least within a given subgenus), rootstock selection can potentially influence long-term graft compatibility, regional adaptability, and disease resistance that may take years to manifest.

There is little information on how ploidy levels might influence graft compatibility and scion/rootstock relationships, but it is well documented that ploidy can influence cell size, rate of growth, gene expression, and a host of other morphological and physiological characteristics. In tea (*Camellia sinensis*) the ploidy of the rootstock influenced the shoot density of the scion (Bore et al., 2006). With magnolias, variation in ploidy is also associated with particular species and taxonomic sections, and is thus somewhat correlated with phylogeny. So, with all other things being equal, a similar ploidy in the scion and rootstock may be desirable.

Disease resistance and tolerance to poor drainage (hypoxia) are also important considerations in rootstock selection. A number of diseases can infect the root system and rootstock stem of magnolias including *Botryospheria dothidea*, *B. obtusa*, *Cerrena unicolor*, *Cylindrocladium* spp., *Ganoderma lucidum*, *Nectria* spp., *Oxyporus latemarginatus*, *Phytophthora* spp., *Schizophyllum commune*, and *Verticillium* spp. (Sinclair and Lyon, 2005). It is not uncommon to see stem cankers on the rootstock stem of magnolias below the graft union in nurseries and landscapes (Fig. 1). Although there is little information on differential resistance to these diseases among magnolia species and cultivars, they may vary substantially when used as rootstocks. Magnolias also vary considerably in their tolerance to poor drainage. Some species like *M. virginiana* are often native to swampy, riparian habitats and are tolerant of periodic inundation, while others, like *M. sieboldii* are typically found in more mountainous habitats and are relatively intolerant of poorly-drained soils (Callaway, 1994; Gardiner, 2000).

Fig. 1. *Magnolia* 'Rose Marie' grafted on an unidentified rootstock with a stem canker.

It is difficult to study long-term compatibility and performance of tree rootstocks in a formal manner and issues like herbicide damage, poor soil conditions, or low planting depth can sometimes be confused with rootstock or grafting problems. However, astute propagators have made valuable observations. Lane (1993) reported good success grafting *M*. ×*wiesneri* (*obovata* × *sieboldii*) onto *M. obovata* (syn. *hypoleuca*) in subgenus *Magnolia* and *M. campbellii*, *cylindrica*, *dawsoniana*, *sprengeri*, 'Albatross', and 'Yellow Bird' onto *M*. 'Heaven Scent' (a complex hybrid among *M. campbellii*, *denudata*, and *liliiflora* - 5*x*) in subgenus *Yulania*. Hooper (1990, 2010) conducted long-term observations on many magnolia scion/rootstock combinations and found differential growth of the scion and rootstock stem caliper was a common problem and that *M. campbellii* hybrids in particular tended to outgrow many rootstocks. Combinations that did work well included *M.* ×*brooklynensis* (*acuminata* × *liliflora*) and other *M. acuminata* hybrids on *M*. ×*loebneri* (*kobus* × *stellata*) 'Merrill' and that 'Merrill' appeared to be more resistant to root diseases than most *M. kobus* seedlings under their conditions. Also, *M. campbellii* cultivars and hybrids including 'Caerhays Belle', (Raffillii Group) 'Charles Raffill', (Raffillii Group) 'Kew's Surprise', and 'Mark Jury' worked well on the vigorous *M.* ×*soulangeana* (or possibly *M.* ×*veitchii*) 'San Jose' as did *M. doltsopa* 'Silver Cloud'. Hooper (2010) also reported that although *M*. 'Genie' grew well when grafted onto *M. kobus*, flowering was more precocious when grafted onto *M.* ×*soulangeana* including seedling from *M*. 'Rustica Rubra'. Dummer (1979) reported on successful graft combinations in magnolias and suggested grafting *M. campbellii* cultivars on *M. campbellii* seedlings or *M*. ×*soulangeana; M*. 'Charles Coates' (*sieboldii* × *tripetala*), *fraseri*, *officinalis*, *sieboldii*, and ×*wiesneri* on *M*. *tripetala* or *M*. *obovata*; *M*. *acuminata* on *M. kobus*; *M. cylindrica*, *dawsoniana*, and *sprengeri* on *M.* ×*soulangeana*; and *M. acuminata*, *salicifolia*, ×*thompsoniana*, and *virginiana* on *M. kobus*. Charles Tubesing (pers. commun.) had good long-term success (25+ years) grafting *M. campbellii* and *sargentiana* onto seedlings of *M. sprengeri* var. *diva* grown in British Columbia. Tubesing also reported that although he had good results grafting *M. acuminata* hybrids onto seedling *M. acuminata* understocks, this species is not the most amenable to container culture.

Alternatively, he has had good initial success grafting *M.* 'Savage Splendor', 'Blushing Belle', and 'Rose Marie' onto rooted cuttings of 'Yellow Lantern', a hybrid of *M. acuminata* × *M.* ×*soulangeana* 'Alexandrina'. As a further example of how rootstocks can enhance regional adaptability, Tubesing also observed that grafting *M. sieboldii* onto *M. tripetala* produced better, longer-lived trees growing in silt/clay soils at the Holden Arboretum in Kirtland, Ohio, than did *M. sieboldii* when grown on its own roots. Brian Humphrey, a highly experienced magnolia propagator in the United Kingdom, has steered away from using *M. campbellii*, *denudata*, *sieboldii*, ×*soulangeana* as understocks due to poor root system quality, lower initial graft success, and reduced growth rates for scions such as *M.* 'Jurmag 1', Black Tulip™ hybrid magnolia, 'Jurmag 2', Felix Jury™ hybrid magnolia, 'Iolanthe' and *Magnolia sargentiana* var. *robusta* 'Trengwainton Glory' (pers. commun.). Humphrey generally prefers using *M. kobus*, *stellata* (e.g., 'Royal Star'), ×*loebneri* (e.g., 'Leonard Messel), *liliiflora* 'Nigra', and particularly the de Vos / Kosar Little Girl hybrids (*M. liliiflora* ×*stellata*) as understocks since they root readily from cuttings, graft well, and produce vigorous plants. He further reported that plants of *M.* 'Star Wars', 'Spectrum', and 'Galaxy' have performed well grafted onto *M. kobus* for over 28 years in the United Kingdom and that plants of *M. doltsopa*, *figo*, and 'Jack Fogg' grew well when grafted onto *M. stellata* and the Little Girl hybrids.

Using seedlings of *M.* ×*soulangeana* for understocks could be a bit of a gamble. *Magnolia* ×*soulangeana*, a cross between *denudata* (6*x*) and *liliiflora* (4*x*), produces F_1 pentaploids (5*x*). Plants with an odd number of chromosome sets (anisoploids) like this tend to produce offspring with variable chromosome numbers (aneuploids) and phenotypes, if they have any fertility at all. Advanced generations of *M.* ×*soulangeana* can vary considerably in form and vigor with ploidy ranging from 4.6 to 8.5*x* (Parris et al., 2010). Using clonal selections of *M.* ×*soulangeana* as rootstocks, like *M.* 'Alexandrina', 'Rustica Rubra', or related hybrids like *M.* 'Galaxy', 'Heaven Scent', 'San Jose', or 'Yellow Lantern' would be more consistent. Another advantage of using desirable scion cultivars as clonal understocks is that the rootstock of any failed grafts can be grown on for sale as a premium own-rooted cultivar. Of course, rootstock suitability may vary considerably by location, climate, soil conditions, and disease pressure.

In attempts to summarize this information and organize it in a phylogenetic and cytogenetic framework, a list of some commonly grown scion taxa are presented by subgenus, section, and ploidy with suggestions for candidate rootstocks (Table 1; Note: It should be emphasized that these candidate rootstocks are merely suggestions for experimentation and have not necessarily been tested). From a graft compatibility standpoint, it is generally safest to use a rootstock that is closely related to the scion. However, from a practical standpoint, one has to work with rootstocks that are currently available and other gains in disease resistance, cold hardiness, soil adaptability, and precocious flowering may be had by selecting rootstocks from other sections and ploidy levels, but preferably from the same subgenus. Ultimately, using clonal rootstocks that root readily from stem cuttings would provide more consistency and allow for critical testing and evaluation of specific scion/rootstock combinations if the added cost could be justified. For example, experimenting with specific cultivars of *M.* ×*loebneri* like *M.* 'Leonard Messel', 'Merrill', or 'Spring Snow' as understocks might provide improved and more consistent performance than seedlings of *M. kobus*. Cultivars like *M.* 'Alexandrina', 'Galaxy', 'Heaven Scent', 'Lennei', 'Rustica Rubra', 'Yellow Lantern', the Little Girl hybrids, and other cultivars that root readily from cuttings might be tested more extensively as rootstocks rather than seedlings of *M.* ×*soulangeana*. From a practical approach, it would be desirable to identify what own-rooted magnolias do well in any particular area and consider using those as candidate rootstocks for related scions. In many cases, disease resistance, regional adaptability, growth rate, and low suckering may be more important for rootstock selection than strict relatedness, at least within a subgenus.

With greater understanding of the phylogeny, cytogenetics, and propagation of magnolias, the opportunities for developing and growing new hybrids continues to escalate. The future of cultivated magnolias is bright.

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