Magnolia Chromosomes

By August E. Kehr

Chromosomes are the basic carriers of the genes governing inheritance. In counting the chromosomes of the various magnolia species one finds that the most frequently occurring number is 38. These 38 chromosomes are made up of 19 pairs of basic chromosomes. Each pair is identical. The chromosomes in a non-dividing cell are coiled into a tight ball that comprises the cell nucleus.

In the genus *Magnolia* chromosome numbers have been reported ranging from 38 to about 152. In theory a magnolia with only one set of 19 chromosomes would be a viable plant, though no plant with fewer than two sets, or 38 chromosomes, has ever been reported in the genus. Thus the range for magnolias could be as shown in the following chart:

No. of sets of chromosomes	No. of chromosomes	Designation	Some examples in magnolias
1	19	monoploid	none reported, but all parts of these plants would be diminutive in size.
2	38	diploid	macrophylla, dealbata, fraseri, pyramidata, hypoleuca, officinalis, virginiana, sieboldii, globosa, sinensis, wilsonii, stellata, biondii, kobus, cylindrica, salicifolia.
3	57	triploid	hybrids of liliflora × stellata such as the 'Eight Little Girls.'
4	76	tetraploid	acuminata, liliflora, grandiflora hybrids with virginiana such as 'Freeman,' and hybrids of acuminata × liliflora such as 'Woodsman'; also 'Charles Dickens.'
5	95	pentaploid	hybrids of acuminata × denudata such as 'Elizabeth' and 'Sundance'; hybrids of species in the Yulania and Theorhodon sections with species in the Tulipastrum Section.
6	114	hexaploid	species of the Yulania section including denudata, dawsoniana, campbellii, sprengeri, sargentiana, zenii, amoena; also grandiflora (Theorhodon section).
7	133	septaploid	'Lennei,' 'Grace Mc Dade.'
8	152	octaploid	'Rustica Rubra,' 'Picture.'
9	171	nonaploid	none reported
10	190	decaploid	none reported
11	209	undecaploid	none reported
12	228	duodecaploid	possibly a doubled form of sprengeri 'Diva' (see companion article).

From a plant hybridization viewpoint all the foregoing plants would have a fair to good level of fertility with the exception of monoploids and triploids. Monoploids are 100 percent sterile and triploids are nearly 100 percent so. Pentaploids, with their higher chromosome number, are semi-fertile to fully fertile, especially as pollen parents.

It can be noted that by far the greater part of the cultivated species are diploid. In general diploids are considered more primitive than the higher ploidy species, a condition that probably arose by natural doubling of chromosome number of earlier-existing diploids. The ancestral diploids of present day polyploid species probably no longer exist.

From other plant studies it's generally accepted that a diploid plant with its chromosome number doubled to the tetraploid level will be only semi-fertile. This is because the chromosomes are arranged at random in pairs, threes, and even fours in the development of the egg and pollen cells. However, in subsequent generations the chromosomes of newly formed polyploids, for some unknown reason, tend to become "diploidized,' and hence increasingly arranged in pairs. As this happens the fertility after four or more generations increases to the point that the tetraploid and hexaploid plants are highly fertile, as are the examples of tetraploid and hexaploid species shown in the foregoing chart.

When a high chromosome plant is hybridized with a low chromosome plant the characteristics of the progeny normally tend to be intermediate between the two parents, despite the disparity of chromosome numbers. A possible exception: when magnolias of the lower chromosome numbers (diploids and tetraploids) are hybridized with the hexaploid *M. grandiflora* the latter's characteristics tend to be dominant in the progeny. This is probably an exception rather than the rule and more nearly reflects the dominant genes in *M. grandiflora* instead of the higher chromosome numbers per se in that plant.

Thus far we have discussed plants with complete sets of chromosomes from 1 set to 12 sets. It should be repeated that to be viable a magnolia plant must have at least one complete set of 19 chromosomes. When that vital requirement is met, it is then theoretically possible for a plant to exist with any combination of additional chromosomes — from a minimum and theoretical 20 chromosomes to 228 or even more. Magnolia plants with a chromosome number not divisible by 19 are called aneuploids. Magnolia aneuploids have arisen most commonly by subsequent hybridization of pentaploids such as the Soulangiana hybrids. In addition, both 'Elizabeth' and 'Sundance' when used as parents can give rise to aneuploid plants.

Aneuploid plants, especially among the high chromosome types, are significant from both the evolutionary and horticultural standpoints. From the evolutionary viewpoint they provide unusual opportunities for chromosomal reassortment, chromosomal rearrangements, and mutations that can give rise to plants with new and unexpected characteristics, such as increased cold hardiness. Cold hardiness will be discussed later in this article. Horticulturally, these new characteristics provide opportunities for selection of plants with highly desirable new traits. Aneuploids occur only rarely in the lower chromosome range, and are most commonly weak growing. However, they can be sources of desirable dwarf plants and an occasional low chromosome aneuploid could thus be valuable.

In this regard it would be interesting to learn the chromosome number of the very diminutive form of *M. liliflora* discovered by Oz Blumhardt in New Zealand and registered under the name

'Minnie Mouse.' I suspect this plant is either an aneuploid or a diploid derived from functioning of an unfertilized egg cell, thereby reducing the chromosome number by half. Reduction in chromosome number occcurs in rare cases when either the egg cell or pollen cell chromosomes fail to function but the unfertilized cell does function and develops into a plant.

Aneuploids usually are low in fertility and have an unstable breeding behavior. Usually the unevenly matched chromosomes tend to be lost, and in subsequent generations the chromosome number will tend to move toward even ploidy numbers, namely, diploid, tetraploid, hexaploid. This is because a chromosome without an identical partner tends to be lost in cell divisions that occur in the formation of egg and pollen cells.

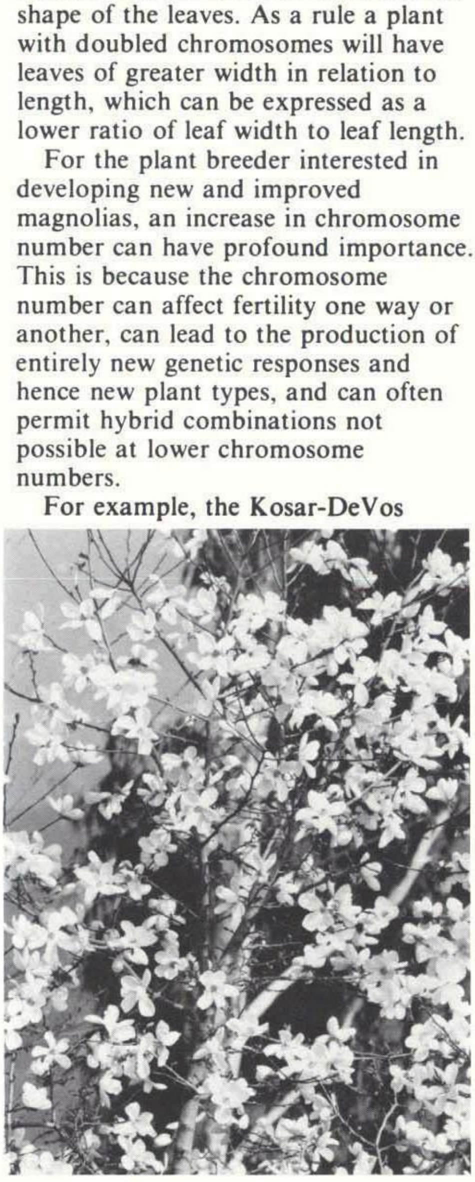
Some mutations that would be lethal to the plant at the low chromosome range are likely to survive in a cell millieu of plants with a larger number of chromosomes.

An increased number of chromosomes most commonly brings about an increase in size of the affected cells as compared to unaffected cells on the same plant, or similar plants of that species. Compared to diploids, polyploid plants of the same species also show changes in height and width, in increased thickness of branches, in size, shape, and texture of leaves and flowers, in slightly reduced fertility of the flowers, and in genetic and physiological responses. The changes of greatest importance in most ornamental plants are increased size of flowers; thickening of flower texture, which tends to increase their lasting qualities; and alteration of genetic or breeding behavior.

The changes that may occur when the chromosome number of a given plant is increased cannot always be accurately predicted, however. There are examples where an increase in chromosome number results in almost undetectable visual differences. In such cases the only certain way to determine if there has been a change in chromosome number is by counting the chromosomes cytologically under a high power microscope with an oil immersion lens that has a magnification of 1800-2000X. Fortunately, with most plants, strong evidence of an increase in chromosome number can be observed in the altered shape of the leaves. As a rule a plant with doubled chromosomes will have leaves of greater width in relation to length, which can be expressed as a lower ratio of leaf width to leaf length.

For the plant breeder interested in developing new and improved magnolias, an increase in chromosome number can have profound importance. This is because the chromosome number can affect fertility one way or another, can lead to the production of entirely new genetic responses and hence new plant types, and can often permit hybrid combinations not possible at lower chromosome numbers.

For example, the Kosar-DeVos



Magnolia 'Norman Gould.'

hybrids commonly called the Eight Little Girls are hybrids of *M. liliflora* (tetraploid) with *M. stellata* (diploid) and are thus all triploids. As triploids they are highly sterile, or even completely sterile. If, however, their chromosome number were to be doubled, the resulting hexaploid plants would be expected to be highly fertile, and as such usable in further breeding work.

Likewise, in the aforenamed hybrid combination, if the cross were to be between *M. liliflora* (tetraploid) with a tetraploid form of *M. stellata*, the resulting hybrid would be tetraploid and as such would be semi-fertile and usable in further breeding.

Other examples of some of these effects are not readily forthcoming in magnolia literature, largely because so little work has been done to date in the genus. The only examples of induced polyploids in magnolias are represented in work done by Dr. Janaki Ammal in development of two polyploid plants in *M. stellata*. These have been named 'Norman Gould' and 'Janaki Ammal.' To my knowledge neither has been used further in breeding work, nor has a description been given of the flower characteristics or the use of these clones as parents, as compared to their diploid relatives. Accurate original records on both of these plants are not available and there is even uncertainty as to whether these cultivars are *M. stellata* or *M. kobus.*

However, an example in Rhododendrons can be used to illustrate the points noted. Germinating seeds of *Rhododendron carolinianum*, a diploid, were treated with a 0.25 percent solution of colchicine. From thousands of seedlings a doubled form was obtained by the author of this article.

The flower size was much larger and thicker textured than any normal diploid and, unlike the normal diploid, the flower opened so widely it reflexed backward (see photo). It was registered as 'Epoch.' 'Epoch' is fully fertile, and produces seed larger than the normal diploid. Likewise its breeding behavior

Flower of tetraploid Rhododendron carolinianum *'Epoch' (at left) with flowers of three diploid clones of same species. Note larger size and reflexed petals of tetraploid.*

differs from the diploid version. Hybridization between the normal diploid, *R. carolinianum*, and the tetraploid species *R. augustinii*, is difficult or almost impossible, and the one known hybrid is weak-growing and completely sterile. On the other hand, hybrids between 'Epoch' and *R. augustinii* are easy to accomplish; the seedlings show hybrid vigor, and are fully fertile, either as male or female parents. Changes such as these can be expected in polyploids of magnolias.

Doubled forms not only have the chromosome number doubled, but the number of genes is also doubled, producing a change in the genetic behavior of the doubled forms when compared to their original undoubled counterparts. Mendelian ratios in polyploid plants are exceedingly complex as compared to diploid ratios. This doubling of the genes confers distinct advantages upon the plant in that its reservoir of genetic material is increased. It's well known that the plants of arctic regions are predominantly polyploids, although plant scientists differ in their explanations of this phenomenon.

Newly produced polyploids are no hardier than their lower chromosome counterparts, but later generations of the polyploids, with their greater reservoir of available genetic material, do develop new characteristics more readily than diploids, for example. One may wonder whether selfing of the *Magnolia* × *soulangiana* hybrids with their high chromosome numbers would not result in eventual increased hardiness if the offspring were subjected to conditions cold enough to bring about selection for hardiness.

The author of this article believes it is likely that increased hardiness could be achieved by growing large numbers of *M.* × *soulangiana* seedlings and selecting for hardiness in these populations of high-chromosome-number aneuploid plants. I believe this is how the present day sub-arctic plants with high chromosome numbers arose. There can be no doubt that the development of aneuploid progeny so frequent in polyploids leads to totally new and unexpected kinds of plants not possible at normal diploid chromosome levels.

Many of the commercial plants of field and garden are polyploids. Examples include wheat, oats, strawberries, sweet potatoes, potatoes, bananas, most bramble crops, tobacco, cotton, sugar cane, apples, plums, and pears. Interestingly, polyploidy is almost nonexistent in the animal kingdom, even in the lower forms.

In magnolias a majority of the named cultivars are polyploids. For example, in Treseder's superb book, "Magnolias," a total of 159 cultivars was named in the index, of which 121, or 76 percent, are polyploids. This high percentage of polyploids would not be expected when one takes into account that in the same book, of the 39 species for which chromosome counts were given, only 12, or 39 percent, were polyploids. It could be that polyploid hybrids with their larger flowers are more often selected and named than diploid hybrids with their less spectacular sized flowers. It is an anomaly that one species in the genus with some of the largest flowers, *M. macrophylla*, is a diploid. I wonder what a polyploid of *M. macrophylla* would look like. Perhaps some day I shall see!