The Chinese *Parrotia:* A Sibling Species of the Persian *Parrotia*

Jianhua Li and Peter Del Tredici

The Persian ironwood *(Parrotia persica)* has a well-deserved reputation as a beautiful garden plant—mainly because of its exfoliating bark and gorgeous fall color—but also as a tough species that tolerates drought, heat, wind, and cold (Dirr 1998). Less well known is the fact that Persian ironwood has a sister species, the Chinese ironwood *(Parrotia subaequalis)* (Figure 1), growing about 5600 kilometers (3500 miles) away in eastern China. Remarkably, this species was correctly identified only sixteen years ago (Deng et al. 1992a).

The Persian and Chinese ironwoods are members of the witch hazel family (Hamamelidaceae), and in order to appreciate their uniqueness and evolutionary history we need to first examine one of their more familiar relatives, the witch hazels *(Hamamelis).* There are five species of witch hazel distributed throughout the temperate regions: *H. mollis* in eastern China, *H. japonica* in Japan, and *H. virginiana, H. vernalis, H. mexicana* in North America. The genus shows the intercontinental disjunct distribution between eastern Asia and North

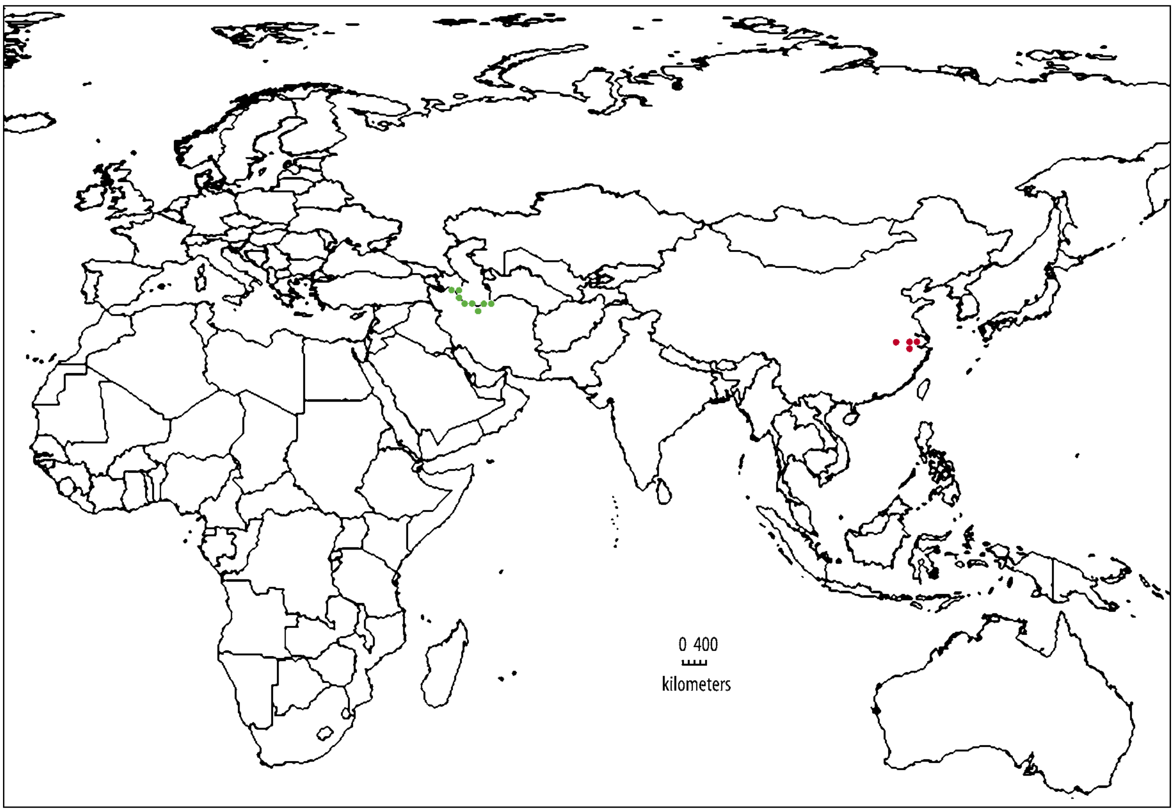

Figure 1. Geographic distribution of *Parrotia persica* (in green) and *P. subaequalis* (in red). Note that the scale bar is 400 kilometers.

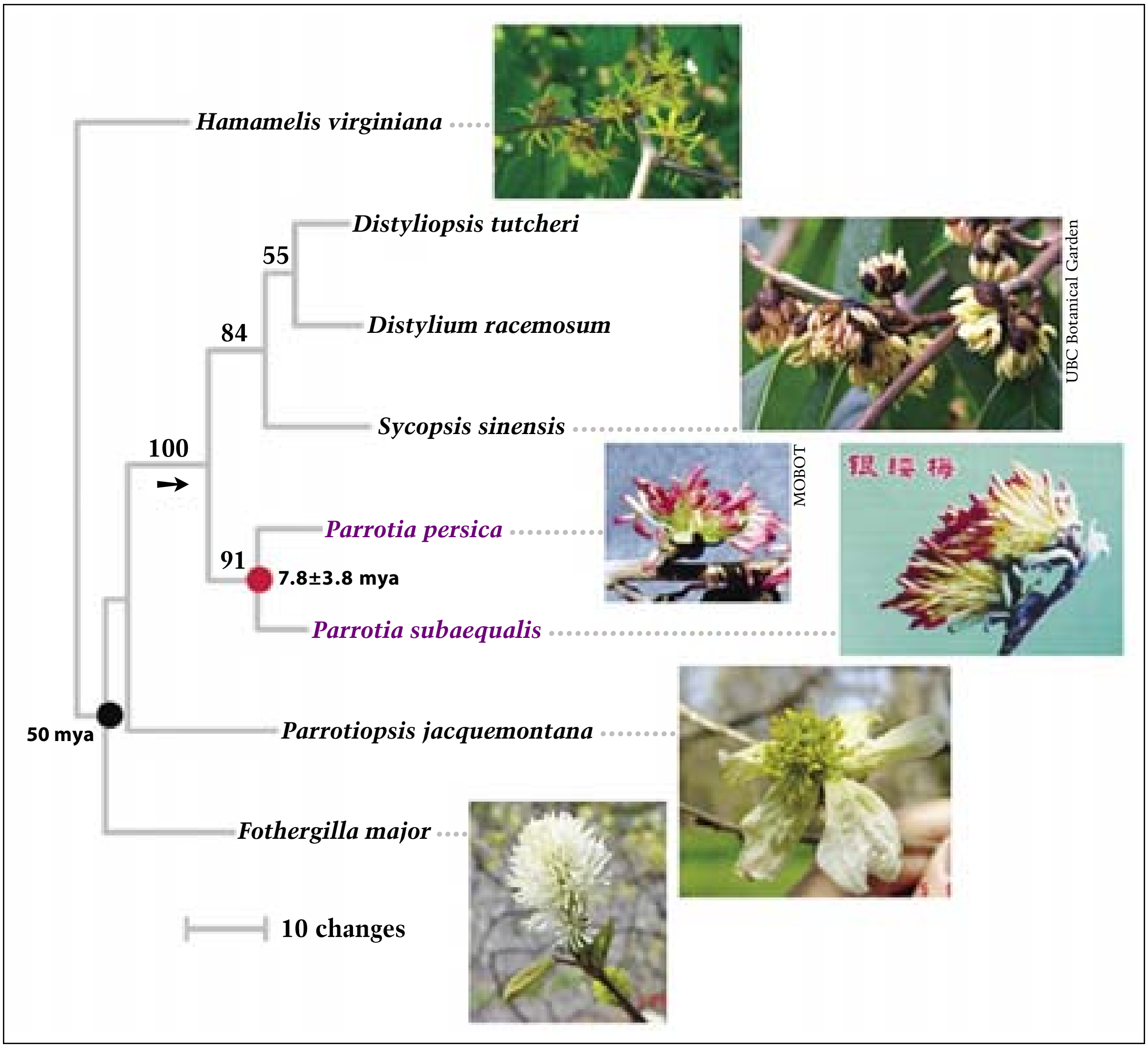

Figure 2. Evolutionary relationships of *Hamamelis* and petalless genera, showing shift (the arrow) from insect to wind pollination. Black dot indicates the fossil calibration point and the red dot shows the divergence time of the two *Parrotia* species.

The scale bar represents ten changes in nucleotide composition as measured along the horizontal branches of this phylogenetic tree. Changes in nucleotide composition indicate genetic evolution over time.

The numbers that appear over several of the branches indicate the percentages of statistical support for those groupings. Higher numbers indicate stronger evidence of support.

(mya=million years ago)

America that has fascinated many scientists since the time of Asa Gray (Gray 1846).

Witch hazels have four ribbonlike petals (Figure 2) that come in a variety of colors from yellow to reddish copper. Six other genera in the witch hazel family have similar ribbonlike petals and occur in Southeast Asia, Africa, Madagascar, and northeastern Australia. These genera have traditionally been considered closely related to one another and to *Hamamelis* because they have the same number of similarly shaped petals.

But recent DNA analysis has determined that the genera with four ribbonlike petals do not form a closely related natural group because they are positioned on different branches in the

P. DEL TREDICI

Figure 3. The foliage of a specimen of *Parrotia subaequalis* growing at the Nanjing Botanical Garden.

witch hazel family tree. Interestingly, in each branch of this family tree the most advanced genera are those that have lost their petals, a trait that is generally believed to correlate with the transition from insect to wind pollination (Li et al. 1999). During this evolutionary transition period, a few genera in the *Hamamelis*—*Parrotia* lineage developed showy parts other than petals with which to attract insect pollinators. For example, *Parrotiopsis* of the western Himalayas possesses showy leaflike bracts beneath the inflorescences, while *Fothergilla* species in the eastern U.S. have conspicuous white stamen filaments (Figure 2). In contrast, *Parrotia* flowers lack not only petals but also showy bracts and stamen filaments. Instead, their anthers are elongated, a characteristic common to wind-pollinated species including the most advanced genera in Hamamelidaceae. Thus, the shift from insect to wind pollination is complete in the evolutionary branch leading to *Parrotia, Sycopsis, Distyliopsis,* and *Distylium* (Figure 2).

Taxonomic History of the Chinese *Parrotia*

The first recorded species of *Parrotia*—*P. persica*—was described by C. A. Meyer in 1831 and named in honor of F. W. Parrot, a German naturalist and traveler. For a long time it was the only known species in the genus. In 1960 Professor H. T. Chang of Sun Yat-sen University described a new species of *Hamamelis*—*H. subaequalis*—based on a fruiting specimen that had been collected twenty-five years earlier from Yixing county of Jiangsu province, China. Its main distinguishing feature was that it produced much smaller leaves than the Chinese witch hazel *(H. mollis)* (Figure 3) (Chang 1960). The fact that the plant described as *H. subaequalis* was not recollected until 1988—some 53 years after its initial collection—led to speculation that the plant had gone extinct in the intervening years.

In the fall of 1988, Miaobin Deng and colleagues at Jiangsu Institute of Botany discovered a natural fruiting population of *H. subaequalis* in the town of Yixing. After three years of continually monitoring the population, their patience was rewarded when the plants finally flowered again (Deng et al. 1992b). At that point it became clear that *H. subaequalis* lacked petals, making it dramatically different from *H. mollis* (Figure 4). They proposed a new genus—*Shaniodendron*—to accommodate the species which they named *S. subaequale* (Deng et al. 1992a). Dr. Riming Hao, who studied the floral morphology of *Shaniodendron,* pointed out that *Shaniodendron subaequale* was quite similar to *Parrotia persica,* but he did not place it within the genus *Parrotia* (Hao et al. 1996). In 1996, Dr. Yinlong Qiu sent some DNA of *Shaniodendron* to Jianhua Li, then a PhD candidate at the University of New Hampshire working on the systematics of the witch hazel family. He obtained nuclear DNA sequence data from the sample and, after comparing it with other genera of the family, determined that *Shaniodendron* was a sibling species to *Parrotia persica* (Li et al. 1997). After seeing the DNA results, Hao used this evidence to propose the merger of *Shaniodendron* with *Parrotia* (Hao and Wei 1998). Nevertheless, it seems that this

JIANHUA LI

Figure 4. The flowers of *Parrotia subaequalis* as shown on a sign posted at the Yixing Caves Scenic Area.

treatment may take some time for people to accept since recent studies continue to use the name *Shaniodendron subaequale* (Fang et al. 2004; Huang et al. 2005), despite the fact that the plant is listed as *Parrotia subaequalis* in the *Flora of China.*

Parrotia persica and *P. subaequalis* are very similar from growth habit to morphology. Both trees display exfoliating bark, have obovate leaves with bluntly toothed margins, and grow in moist habitats along streams. They bear four to seven flowers clustered in a head inflorescence subtended by broadly ovate, brownish bracts. Each flower has five sepals but no petals and four to fifteen stamens with long anthers (Figure 4). Their fruits are woody capsules consisting of two chambers, each with two brown seeds (Figure 5). *Parrotia subaequalis* can be easily distinguished from *P. persica* by its lanceolate stipules and sepals fused into a shallow saucer-shaped calyx (Hao et al. 1996).

When did *Parrotia persica* and *P. subaequalis* diverge?

Recent DNA work in Jianhua Li's laboratory has shown that witch hazels *(Hamamelis)* are more primitive than the petalless genera in Hamamelidaceae. The evolutionary sequence of the petalless genera appears in the order of *Fothergilla, Parrotiopsis, Parrotia, Sycopsis,* and *Distyliopsis* plus *Distylium,* and the two species of *Parrotia* are grouped together (Figure 2).

Fossils can provide evidence for the minimum age of the lineage to which they belong. Unfortunately, fossil information is often unavailable for a specific taxon. Nevertheless, if DNA molecules evolve at a constant rate, that is, a certain number of nucleotide changes per million years, we can use the total number of changes between the two species to estimate how long ago they diverged. Our statistical tests indicated that the evolution of the nuclear genes we have used to reconstruct the evolutionary history of these genera followed a clockwise manner. The next thing we needed was to calibrate the ticking rate of the molecular clock using one or more known fossil dates. Luckily, Radtke et al. (2005) found a fossil leaf that could be unequivocally assigned to *Fothergilla,* specifically *F. malloryi.* This fossil leaf is part of the Republic Flora of northeastern Washington State, dating to the late Eocene (about 50 million years ago), and thus provides a minimum separation age of *Fothergilla* from the branch leading to other genera (Figure 2). Based on the molecular clock calibrated using the fossil, our estimates suggest that the two species of *Parrotia* diverged around 7.5 million (plus or minus 3.8 million) years ago, during the Lower Miocene. This divergence time is consistent with the geological evidence

JIANHUA LI

Figure 5. Fruit and seed of *Parrotia subaequalis.*

P. DEL TREDICI

Figure 6. *Parrotia subaequalis* cultivated as penjing at the Nanjing Botanical Garden.

that the cooling temperature in the Lower Miocene plus the uplifting of the Himalayas and the mountains of western China from 55 million years ago to the Middle Miocene may have restricted biological exchanges between central Asia and eastern China (Yin and Harrison 2000; Sun and Wang 2005).

Forests in the Caspian region of central Asia and those in eastern Asia are both relicts of the widespread Tertiary vegetation (Wolfe 1975; Hosseini 2003; Sun and Wang 2005). Besides *Parrotia,* the two regions share many other woody plant genera including *Acer, Albizia, Buxus, Castanea, Carpinus, Diospyros, Fagus, Pterocarya, Quercus, Sorbus, Taxus,* and *Zelkova.* From an evolutionary and biogeographical standpoint it would be interesting to determine whether central Asian species within these genera are siblings of the eastern Asian species, and if so, whether their separation time agrees with that between the two *Parrotia* species.

Parrotia subaequalis in China

According to Chengxin Fu, Riming Hao, and various accounts in the literature, there are five populations of *Parrotia subaequalis* in eastern China: two each in Jiangsu and Zhejiang provinces (Huang et al. 2005) and one in Anhui (Shao and Fang 2004). Professor Fu's team is currently conducting a survey to determine the levels and patterns of the genetic diversity in Chinese *Parrotia* populations. The results will provide a scientific foundation for designing conservation strategies. Regeneration of *Parrotia subaequalis* populations will be challenging because of the species' alternate-year fruit production, serious habitat competition from bamboos, and increasing human activities. It is essential to take immediate action and institute stricter measures to protect the species.

Peter Del Tredici first saw two plants of *Parrotia subaequalis* on October 8, 1994. They were being cultivated in containers as penjing (bonsai) in a lath-house at the Nanjing Botanical Garden. At that time, the foliage had turned a beautiful, rich, deep red (Figure 6). According to the Director of the Garden, Professor Shan-an He, the plants had been collected in Jiangsu province at the Yixing Caves Scenic Area, which is located about 120 kilometers (75

P. DEL TREDICI

Figure 7. Dr. Hao Riming of the Nanjing Botanical Garden with a plant of *Parrotia subaequalis* grown from a cutting.

miles) southwest of Nanjing on the east side of Tai Lake. Both specimens had massive trunks and the larger of the two was about 50 centimeters (20 inches) tall by 70 centimeters (28 inches) across. The form of their trunks, along with their extensive yet well-healed wounds, suggested that both plants were very old. When Peter returned to the Nanjing Botanical Garden in September of 1997, he didn't see the penjing specimens but saw one young plant—recently propagated from a cutting and about 2 meters (6.6 feet) tall—growing out on the grounds of the garden (Figure 7).

On September 1, 2004, we [Del Tredici and Li] had the good fortune to be able to visit the Yixing Caves Scenic Area (known as Shan Juan Park) with Professor Cheng-xin Fu and Ying-xiong Qiu of Zhejiang University. Upon entering the park, the group immediately encountered a large specimen of *Parrotia subaequalis* growing on a steep slope above a small pond at the mouth of the largest of the karst caves. The plant was hard to miss because it was identified with a large sign with a close-up color photograph of the plant in bloom (Figure 4). The tree, which was about 6 meters (20 feet) tall, had two main trunks, the largest of which was 24 centimeters (9.4 inches) in diameter (Figure 8). The bark appeared to be at the peak of its exfoliation, with patches of fresh greenish white bark showing where sections of the old bark had sloughed off. There were no fruits on the plant—the species typically flowers only every other year—but there were numerous seedlings growing beneath it.

A second large specimen was spotted about 30 meters (100 feet) away, on a slope in a mixed woodland with bamboo and other trees. We observed at least two cases where the exposed roots of this plant were producing vigorous young suckers, a phenomenon which had not been reported in the literature (Figure 9). Interestingly, sprouting from the base of the trunk was not observed on any of the trees.

Later that afternoon, the group drove to Longwang Shan in Anji Xian, in northern Zhejiang Province, about 90 kilometers (56 miles) south of the Yixing Caves. This relatively small mountain is considered part of the larger Tian Mu Shan range that forms the border with

JIANHUA LI

Figure 8. The trunk and foliage of a *Parrotia subaequalis* specimen growing at the Yixing Caves Scenic Area.

P. DEL TREDICI

Figure 9. Root suckers from a mature specimen of *Parrotia subaequalis* at the Yixing Caves Scenic Area.

P. DEL TREDICI

Figure 10. *Parrotia subaequalis* on Longwan Shan, 9.5 meters (31 feet) tall with a diameter at breast height of 38 centimeters (15 inches).

Anhui Province. After spending the night in comfortable accommodations at the research station, we hiked partway up the mountain to about 650 meters (2,130 feet) elevation and located two specimens of *Parrotia subaequalis* growing near the side of a stream, amidst a pile of boulders. The larger of the two trees was about 9.5 meters (31 feet) tall with a trunk diameter at breast height of 38 centimeters (15 inches) (Figure 10). Its bark was exfoliating in a dramatic way—shedding jigsaw-puzzle-shaped plates of old, blackish brown bark to expose conspicuous patches of greenish white bark below (Figure 11). The second specimen had a double trunk, was about 8 meters (26 feet) tall, and its bark was not exfoliating as dramatically as the larger plant. Neither was producing any sprouts from the base of its trunk or any root suckers. Unfortunately there were no fruits on either plant, although there were curious hard, round, gall-like structures about a centimeter or so in diameter on many of the leaves of the smaller, double-trunked plant. Some of the notable associates growing with *Parrotia subaequalis* on Longwang Shan were *Fortunearia fortunei, Styrax confusus, Pterostyrax corymbosum, Cornus controversa, Stewartia rostrata,* and *Stewartia sinensis.* We were told that the *Parrotia subaequalis* population at Longwang Shan consisted of about twenty individuals at that time.

P. DEL TREDICI

Figure 11. This specimen of *Parrotia subaequalis* (same plant seen in Figure 10) shows a very knobby trunk, indicating that it has lost many lower branches over time.

Parrotia subaequalis at the Arnold Arboretum

The Arnold Arboretum has two established plants of *Parrotia subequalis.* So far, both of them have survived two winters outdoors and they are now about 1.5 meters (5 feet) tall. On June 23, 2005, during their first growing season at the Arboretum, seven cuttings between 5 and 10 centimeters (2 to 4 inches) long were taken from the two plants. A month later, on July 25, another nine cuttings were taken from the plants. All sixteen cuttings were treated with a five-second dip in an aqueous solution of 5,000 parts per million KIBA, stuck in flats filled with a mix consisting of half sand and half perlite, and placed in the high-humidity greenhouse under intermittent mist and fog. Remarkably, all sixteen of the cuttings rooted and three of them are planted in the nursery.

With five plants now growing outdoors, the Arboretum is in a position to begin evaluating the horticultural potential of *Parrotia subequalis.* Successful establishment at the Arboretum also facilitates continued research on the genetics, physiology, reproductive biology, and conservation of this rare and evolutionarily important species.

Acknowledgments

We thank Cheng-xin Fu and Ying-xiong Qiu of Zhejiang University for their field assistance.

Literature Cited

Chang, H. T. 1960. *Hamamelis subaequalis. Journal of Sun Yat-sen University* 1: 35.

Deng, M. B., H. T. Wei, and X. Q. Wang. 1992a. *Shaniodendron,* a new genus of Hamamelidoideae from China. *Acta Phytotaxonomica Sinica* 30: 57–61.

Deng, M. B., H. T. Wei, X. Q. Wang, P. Su, and J. Y. Xing. 1992b. On the significance of the discovery of Fothergilleae in China. *Journal of Plant Resources and Environment* 1: 30–35.

Dirr, M. A. 1998. *Manual of Woody Landscape Plants.* Stipes Publishing, Champaign, IL

Fang, S., J. Yan, Q. Weng, and S. Huang. 2004. Population ecological status quo and protection study on *Shaniodendron subaequale* M. B. Deng, H. T. Wei in Longchi mountain reserve in Yixing. *Journal of Jiangsu Forestry Science and Technology* 31: 4–6.

Gray, A. 1846. Analogy between the flora of Japan and that of the United States. *American Journal of Science and Arts,* ser. 22: 135–136.

Hao, R. M., H. T. Wei, and W. G. Liu. 1996. Floral morpholgy of *Shaniodendron* (Hamamelidaceae) and its taxonomic significance. *Journal of Plant Resources and Environment* 1(1): 30–35.

Hao, R. M. and H. T. Wei. 1998. A new combination in Hamamelidaceae. *Acta Phytotaxonomica Sinica* 36: 80.

Hosseini, S. M. 2003. Incomparable roles of Caspian forests: Heritage of humankind. *Forest Science* 3: 31–40.

Huang, S., Y. Fang, Y. Peng, J. Yan, and S. Fang. 2005. The niche study of *Shaniodendron subaequale* population of Longchi mountain. *Journal of Central South Forestry University* 25: 80–83.

Li, J., A. L. Bogle, A. S. Klein, and K. Pan. 1997. Close relationship between *Shaniodendron* and *Parrotia* (Hamamelidaceae), evidence from its sequences of nuclear ribosomal DNA. *Acta Phytotaxonomica Sinica* 35: 481–493.

Li, J., A. L. Bogle, and A. S. Klein. 1999. Phylogenetic relationships of the Hamamelidaceae inferred from sequences of internal transcribed spacers (ITS) of nuclear ribosomal DNA. *American Journal of Botany* 86: 1027–1037.

Radtke, M. G., K. B. Pigg, and W. C. Wehr. 2005. Fossil *Corylopsis* and *Fothergilla* leaves (Hamamelidaceae) from the lower Eocene flora of republic, Washington, U.S.A., and their evolutionary and biogeographic significance. *International Journal of Plant Science* 166: 347–356.

Shao, X. F. and G. F. Fang. 2004. Habitat survey and ex situ conservation of *Shaniodendron subaequale. Journal of Anhui Forest Science and Technology* 2: 12–13.

Sun, X. and P. X. Wang. 2005. How old is the Asian monsoon system?—Palaeobotanical records from China. *Paleogeography Paleoclimatology Palaeoecology* 222: 181–222.

Wolfe, J. A. 1975. Some aspects of plant geography of the Northern Hemisphere during the late Cretaceous and Tertiary. *Annals of the Missouri Botanical Garden* 62: 264–279.

Yin, A. and T. M. Harrison. 2000. Geologic evolution of the Himalayan-Tibetan orogen. *Annual Review of Earth and Planetary Sciences* 28: 211–280.

Jianhua Li and Peter Del Tredici are senior research scientists at the Arnold Arboretum.