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Front cover: A grove of birches, *Betula* spp., at the Arnold Arboretum. Photo by Al Bussewitz.

Inside front cover: The fruit of *Rhus typhina*, the staghorn sumac, is bright crimson in early fall, darkens in the cold of winter, and often remains colorful into spring. From *The Sylva of North America* by C. S. Sargent, drawn by C. E. Faxon.

Back cover: The late-summer fruit of *Ailanthus altissima* Photo by Al Bussewitz.

Inside back cover: Winter at the Arnold Arboretum. Photo by Rácz and Debreczy.

Where the Wild *Ginkgos* Grow

Peter Del Tredici

The question of whether there are wild *Ginkgos* in China has bedeviled botanists for years. After visiting Tian Mu Mountain in Zhejang Province, the author concludes that the question may not be as important as it once seemed.

The question of whether or not the *Ginkgo* still exists in the wild has been debated by scientists for over a century. Based on very limited fieldwork in Asia in the late nineteenth and early twentieth centuries, western botanists—including both C. S. Sargent and E. H. Wilson of the Arnold Arboretum—expressed the often-quoted opinion that *Ginkgo* was probably extinct in the wild and that it was saved from total extinction by Buddhist monks who cultivated it in the gardens surrounding their temples. This romantic idea, which was based more on speculation than fact, became embedded in the horticultural literature despite the report in 1915 by F. N. Meyer of the U.S. Department of Agriculture of a large population of *Ginkgos* growing spontaneously in the forests of eastern China. Meyer communicated his discovery in a letter to his superiors in Washington (Cunningham, 1984), but unfortunately he failed to write up any of the details for publication. It was C. S. Sargent and E. H. Wilson who saved Meyer's observations from archival oblivion by quoting from the letter in two separate publications:

> One of the remarkable things about the Ginkgo-tree is the fact that although it has been undoubtedly cultivated by the Chinese for many centuries, the region where it grows naturally and spontaneously has remained unknown, travelers having failed to find any trees growing in the forests or anywhere except in the neighborhood of temples or shrines where they had evidently been planted. A year ago [May, 1915], however, Mr. F. N. Meyer, the well-known botanical explorer for the Department of Agriculture, found the Ginkgo growing spontaneously in rich valleys over some ten square miles near Changhua Hsien, about seventy miles west of Hangchou, in the Chekinag province. There were many seedlings and the trees here were so common that they were cut for firewood, something which has never been seen before in China. It is by no means certain that this is the original home of the Ginkgo as these trees may all have descended from a planted tree. It is exceedingly interesting, whatever may be the history of these trees, to find that there is at least one place in China where the Ginkgo grows in the woods and reproduces itself spontaneously. (Sargent, 1916)

> According to Frank N. Meyer, botanical explorer for the U.S. Department of Agriculture, "the Ginkgo grows spontaneously in rich valleys over some ten square miles near Changhua Hsien, about 70 miles west of Hangchou in the Chekinag province, China." There "the trees are so common that they are cut for firewood." It is however by no means certain that this is the original home of the Ginkgo as these trees may all have descended from a planted tree. Meyer's discovery, however, is interesting, for there is no other evidence of the Ginkgo growing spontaneously or that it is cut for any purpose. (Wilson, 1916)

As presented by Sargent and Wilson, Meyer's discovery is considerably diminished by their unjustified suggestion that a population covering some ten square miles

Figure 1. A view of the south-facing slope of the west peak of Tian Mu Shan, now protected as part of a Chinese government nature reserve.

"may all have descended from a planted tree." Sargent's restatement of Meyer's letter is particularly misleading because no quotation marks distinguish Meyer's words from Sargent's interpretation of them.

Be that as it may, in the late 1920s and 30s, Meyer's discovery was corroborated by Chinese botanists who not only visited Changhua Hsien but also reported the existence of other "wild" populations of *Ginkgo* in the surrounding area, primarily in the vicinity of Tian Mu Shan (Tian Mu Mountain) in Zhejiang Province (Cheng, 1933; Li, 1956; Wang, 1961). In 1956 the Chinese scientific community determined that Tian Mu Shan was of sufficient biological interest to warrant a formal proposal recommending its protection, but it was not until 1960 that the Chinese government acted on the proposal and established the Tian Mu Shan Nature Reserve, encompassing one thousand hectares on the south-facing slope of its western peak.

Despite the establishment of the Tian Mu Shan Reserve, questions about the "wildness" of the *Ginkgo* population have persisted. A detailed census of the population published by the Zhejiang Forestry Bureau in 1984 concludes that the *Ginkgos* are wild, as does Ling Hsieh of the Zhejiang Forestry Bureau (1965). Wang and Chen (1983) and Chen (1989), on the other hand, doubt the wildness of the trees, suggesting instead that they are the offspring of plants that were cultivated in the vicinity of an ancient temple located near the top of the mountain. One

recent report by Wang and his colleagues (1986) concludes ambiguously that "The question of whether this area is part of the natural distribution of wild *Ginkgo* needs further study."

The Tian Mu Shan Environment

At 1506 meters in elevation, the main peak of Tian Mu Shan (119° 25′ E; 30° 20′ N) is one of the highest mountains in Zhejiang Province (Figure 1). The steep slopes are crisscrossed with a network of streams and ridges that create a mosaic of sheltered valleys and exposed cliffs. Subtropical evergreens, typical of south China, mingle with temperate conifers and deciduous plants on the slopes of the reserve, resulting in an exceptionally rich flora consisting of some 1,530 species of vascular plants (Zhejiang Forestry Bureau, 1984; Zheng, 1986). Three distinct vertical zones of vegetation have been described on Tian Mu Shan: (1) between 380-800 meters, a mixed subtropical forest with a canopy of conifers, broadleaf evergreens, and deciduous trees; (2) between 800-1200 meters, a warm-temperate forest with a canopy of conifers and deciduous trees and a subcanopy rich in broadleaf evergreens; and (3) between 1200-1506 meters, a deciduous dwarf forest with a canopy of stunted trees and shrubs.

In addition to its rich species diversity, Tian Mu Shan is also noted for its exceptionally large trees. According to the only published census of the reserve, prepared by the Zhejiang Forestry Bureau in 1984, the most common large tree species is *Cryptomeria japonica* var. *sinensis*, of which there are 398 individuals with a diameter at breast height (DBH) greater than one meter. *Pseudolarix amabilis*, the golden larch, also grows wild on the mountain with some 98 individuals with a DBH greater than half a meter and heights mainly between 40 and 50 meters. Most notably, there are 244 large individuals of *Ginkgo biloba* growing throughout the reserve with a mean DBH of 45 centimeters and a mean height of 18.4 meters. According to the Zhejiang Forestry Bureau report about ten percent of the *Ginkgo* population is estimated to be over a thousand years old.

Along with these three gymnosperms, exceptionally large *Torreya grandis*, *Liquidambar formosana*, *Nyssa sinensis*, *Cyclocarya paliurus*, *Litsea auriculata*, and *Emmenopterys henryi* are also common in the woods, as well as extensive stands of the timber bamboo, *Phyllostachys pubescens*. Three plants are recognized as endemic to Tian Mu Shan, and a total of twenty-nine taxa growing within the reserve are included in Volume One of the *Plant Red Data Book* of rare, endangered, and threatened plants of China (Zheng, 1986; He et al., 1987).

Human Activities on Tian Mu Shan

Located just ninety-four kilometers west of the ancient and populous city of Hangzhou, Tian Mu Shan has been visited by monks, herbalists, poets, botanists, and tourists for close to fifteen hundred years. The most famous structure on the mountain, at 1,020 meters elevation, is Kaishan temple built by Buddhist monks between 1283-1287. Around 1665, a second temple, Chanyuan, was built at 330 meters. Other smaller temples and shrines are located elsewhere on the mountain.

In 1941 the Japanese army invaded the area, bombing the mountainside and ransacking Chanyuan temple. In 1958, during Mao Zedong's "Great Leap Forward," many of the trees in the forest were cut down to make charcoal. When the reserve was established in 1960, only the relatively undisturbed south-facing slope of the west peak was included within its boundaries. Between 1960 and 1965 considerable clean-up was done in the reserve, including the planting of more than a hundred *Ginkgo* seedlings just above the main gate. Maintenance of the reserve was suspended during the ten years of the "Cultural Revolution," from 1966 to

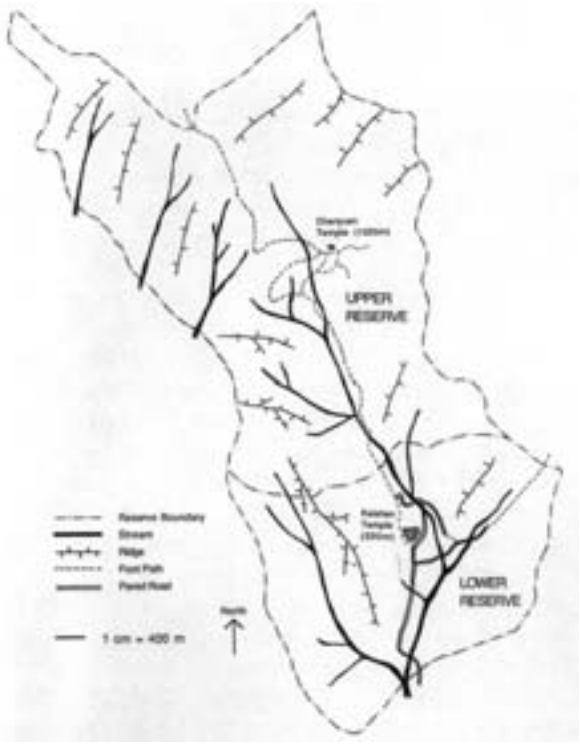

Figure 2. Map of the Tian Mu Shan Nature Reserve. Located on the south-facing slope of the west peak of Tian Mu Shan, the total area of the upper reserve is 652 hectares and the lower reserve 366 hectares.

1976, and effective protection was not achieved until 1982 when construction of the reserve headquarters was completed. Unfortunately, the forests surrounding the reserve are not protected and, as of 1989, they were rapidly being cut, primarily for charcoal manufacture by the local population.

Administratively, the reserve is divided into two sections: the *lower* reserve, covering 366 hectares, which includes the lower Chanyuan temple, numerous hotels, houses and the reserve headquarters. (With the exception of the temple, all of the other buildings were built after 1960.) The *upper*, "special," reserve, consisting of 652 hectares, has experienced relatively little disturbance in comparison (Figure 2). The upper reserve covers both sides of a sheltered valley that extends from 420 meters to the summit at 1506 meters. A stone path, built about a hundred years ago, follows the course of the main stream, crossing it several times, to Kaishan temple. Portions of this path are lined with large *Cryptomerias* that were probably planted at the time of its construction (Del Tredici, 1990). Beyond the temple a narrow footpath leads to the summit where an army weather station is located.

The *Ginkgo* Population

In October, 1989, the author, along with two Chinese collaborators, Ling Hsieh of the Zhejiang Forestry Department and Yang Guang of the Nanjing Botanical Garden, counted the *Ginkgos* growing in the reserve. During the course of our work, we walked all the paths and trails in the reserve and measured and mapped the locations of all the *Ginkgos* that we could locate. *Ginkgo* leaves were turning yellow when we were there, making it easy to locate the trees even at some distance. To be on the conservative side it can be said that we located all the *Ginkgos* within fifty meters of the extensive network of paths.

We measured the DBHs of all trunks greater than 10 centimeters and estimated the heights of all the trees. Unfortunately, the steep terrain of the site and the fact that the top of many trees could not always be clearly seen made accurate height measurements difficult. Under every tree we also made a thorough search of the immediate vicinity for intact seeds or the remains of seeds and for the presence of seedlings. For the purposes of our study, we divided the *Ginkgos* into two groups, those in the upper reserve, which have experienced little disturbance due to human activities, and those in the lower reserve, which have experienced much more human disturbance.

We found a total of 167 spontaneously growing *Ginkgos*, with a mean DBH of 52

Figure 3. Professor Ling Hsieh is dwarfed by Ginkgo *#42, located in the upper reserve. It consists of three large trunks 106.7, 85.3, and 61.8 centimeters in diameter and innumerable small suckers.*

centimeters during the course of the survey, a figure considerably lower than the 244 trees found by the Zhejiang Forestry Bureau in 1984. No doubt this discrepancy is due to our brief stay in the reserve. In ten days' time we did not locate some of the trees that were growing more than fifty meters away from the paths. In the upper reserve, where 72 trees were located, the *Ginkgos* were most common on disturbance-generated microsites, including stream banks, rocky slopes, and the edges of exposed cliffs, all locations where the effects of soil erosion were readily apparent. With the exception of three large trees growing in front of Kaishan Temple, none of the *Ginkgos* in the upper reserve appeared to have been planted. In the lower reserve, where signs of human activities were much more common, many of the 95 censused trees were obviously planted.

The largest *Ginkgo* in the upper reserve had a DBH of 123 centimeters and in the lower reserve it was 121 centimeters. The heights of the larger trees were quite variable, with a maximum of just over 30 meters. The *Ginkgos* were growing between 330 and 1,200 meters elevation, where the terrain has an average slope of seventeen percent. Despite reports of *Ginkgo* seedlings in the woods, we were unable to locate a single plant with a basal diameter less than 5 centimeters. There were only three trees with a basal diameter between 5 and 10 centimeters in the upper reserve, and only two trees within that range in the lower reserve. Clearly the *Ginkgo* population was not actively reproducing from seed under the shady, mature forest conditions that currently prevail on the mountain.

The most striking feature of the Tian Mu Shan *Ginkgos* was the multistemmed form of many of the larger trees (Figure 3). One individual, growing on the edge of a steep cliff at 950 meters occupied a total surface area of approximately twelve square meters and consisted of fifteen stems larger than 10 centimeters DBH (Figure 4). In contrast to such multistemmed trees that were common in the woods, the three cultivated *Ginkgos* growing near the Kaishan temple were all single-trunked specimens. In the upper reserve fifty percent of the *Ginkgos* had at least two trunks greater than 10 centimeters DBH, while in the lower reserve, the figure was one-third. Of these 67 multistemmed trees, the primary trunk was intact in seventy-three percent, clearly indicating

Figure 4. The author standing next to the "living fossil" Ginkgo on Tian Mu Shan. This ancient ovulate tree occupies an area of approximately twelve square meters and consists of fifteen stems greater than ten centimeters in diameter. The fence protecting both the tree and the tourists was built in 1980.

that logging in the area is not the primary cause of secondary sprouting (Figure 5).

Vegetative Reproduction From Basal Chichi

While we could find no signs of recent seedling reproduction on Tian Mu Shan, most of the larger *Ginkgos* were reproducing vigorously from suckers arising near the base of their trunks. In some cases these basal suckers came out of the ground anywhere from two to twenty centimeters away from the trunk, and in others they were attached to large rhizomelike structures that originated from the trunk at ground level. Wherever the base of the trunk of a large *Ginkgo* came into direct contact with a large rock or where its base was exposed by erosion, these structures developed. They either enveloped the rock or grew around it, extending up to two meters from the parent trunk (Figure 6). When these growths reach friable soil, they produce lateral roots, develop vigorous, vertically growing shoots, and continue their downward growth.

Superficially, these structures resemble the well-known "air-roots" produced on old cultivated trees, called "chichi" (nipple or breast) in Japan and "zhong ru" (stalactite) in

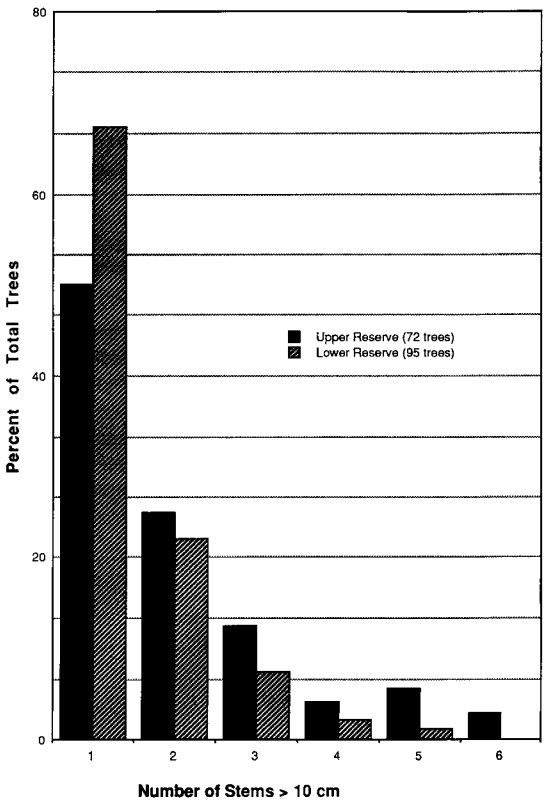

Figure 5. The distribution of the number of stems greater than ten centimeters for 167 Ginkgos *on Tian Mu Shan. Forty percent of the population had more than one stem greater than ten centimeters diameter.*

China. These unusual, downward growing burls form along the underside of large lateral branches. The first anatomical description of chichi was published by Fujii in 1895, who considered them a "pathological formation" that developed in association with an embedded shoot bud.

The only chichi that we saw on the Tian Mu Shan *Ginkgos* were those that originated from the base of trees, particularly those that had experienced damage due to erosion or logging. These growths should be called "basal chichi" to distinguish them from the more familiar "aerial chichi" described above. The strongly clasping nature of this unique structure helps the species survive on sites where disturbance to its root system is a common phenomenon, and no doubt they play a crucial role in the long-term persistence of the species on such sites. Based on subsequent greenhouse work with cultivated seedlings, I have been able to demonstrate that basal chichi develop from suppressed cotyledonary buds (Del Tredici, 1992).

Seed Production and Predation

According to the reserve records, 1989 was a light year for seed production on Tian Mu Shan. In our census work we found intact seeds or the remains of seeds under 54 of 167 trees (32%). Seed drop typically occurs during the last two weeks of September on Tian Mu Shan, depending on the weather. By the time of our arrival on October 3, very few seeds were left on the trees, and we were able to collect more than a hundred seeds from under only two trees. It turns out that most of the nuts had been collected before our arrival by the local populace. The fact that people have been living in the Tian Mu Shan area for at least a thousand years and that *Ginkgo* nuts have long been considered a valuable food and medicine (Li, 1956; Del Tredici, 1991) suggests that the collection of seeds by people could well be an important factor limiting seedling establishment on Tian Mu Shan.

Under every tree that produced seeds in 1989 we found probable signs of feeding activity by the locally abundant red-bellied squirrel (*Callosciurus flavimanus* var. *ningpoensis*). The fleshy outer coat of the seed, which is notoriously foul smelling and can produce a skin rash in animals as well as people, had been pulled off and left uneaten while the edible kernel was consumed, leaving only fragments of the sclerified shell behind. Since we never actually saw squirrels eating or "scatterhoarding" *Ginkgo* seeds, however, their potential role as dispersal agents of *Ginkgo* seeds is still unclear.

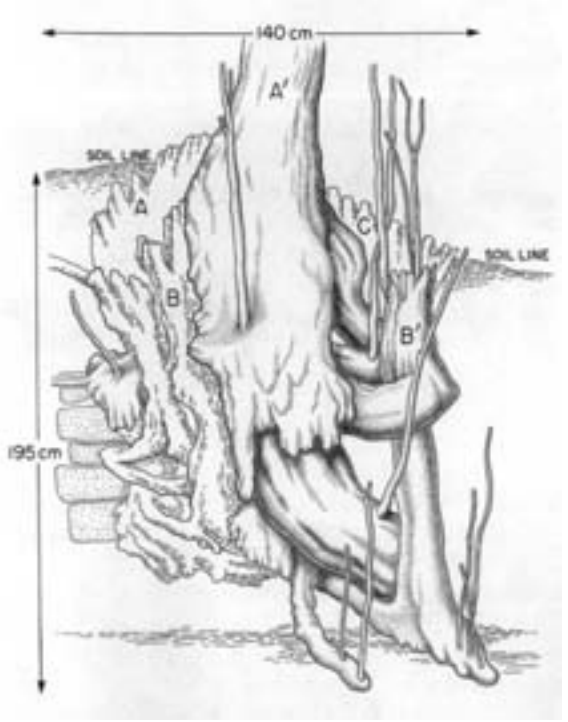

Figure 6. The chichi-developed shoot system of Ginkgo *#163, probably planted, growing over the face of an old rock wall in the lower reserve. At least three generations of stems can be seen: the oldest represented by the cut trunks A, B, and C (diameters = 55, 40, and 37 centimeters); the second by the living trunks A' and B' (diameters = 26 and 20 centimenters); and the third by suckers arising from the zone of active chichi proliferation (stippled). Drawing by Laszlo Meszoly, based on photographs by the author.*

Long-time workers in the reserve reported that a "catlike" animal with a long, thick tail also eats *Ginkgo* seeds in their entirety, vesicatory seed coat and all, and that some of the seeds pass through its digestive system intact. While we did not ourselves see the animal or any signs of its feeding, the workers were probably referring to *Paguma larvata*, the masked palm civet (Viveridae), an omnivorous carnivore (Nowak, 1991) (Figure 7). Interestingly, in the only other study of a "semiwild" *Ginkgo* population located in Hubei Province, Jiang and his colleagues (1990) reported observations of local peasants that the leopard-cat, *Felis bengalensis*, consumes *Ginkgo* seeds and that some of the nuts pass through the cat's digestive system undamaged. The existence of these two independent reports of members of the Carnivora consuming intact *Ginkgo* seeds raises the interesting possibility that the foul smell of the rotting seed coat may be attracting dispersal agents by mimicking the smell of rotting flesh, making *Ginkgo* a carrion mimic, if you will!

Figure 7. The masked palm civet, Paguma larvata. *Photo reprinted with permission from* Walker's Mammals of the World *by R M Nowak.*

Conclusions

Because *Gingko* is an economically important plant and because Tian Mu Shan has been the site of human activities for approximately fifteen hundred years, it is very difficult, if not impossible, to resolve the long-standing argument about the wildness of the *Ginkgo* population. In many ways the debate has more to do with the definition of the term "wild" rather than with the biology of the plant itself. Such semantic considerations should not be allowed to obscure the important biological implications of the Tian Mu Shan *Ginkgo* population that have existed as part of a complex, natural community for a least a thousand years (Figure 8).

More than any other factor, the presence of Kaishan temple has raised doubts about

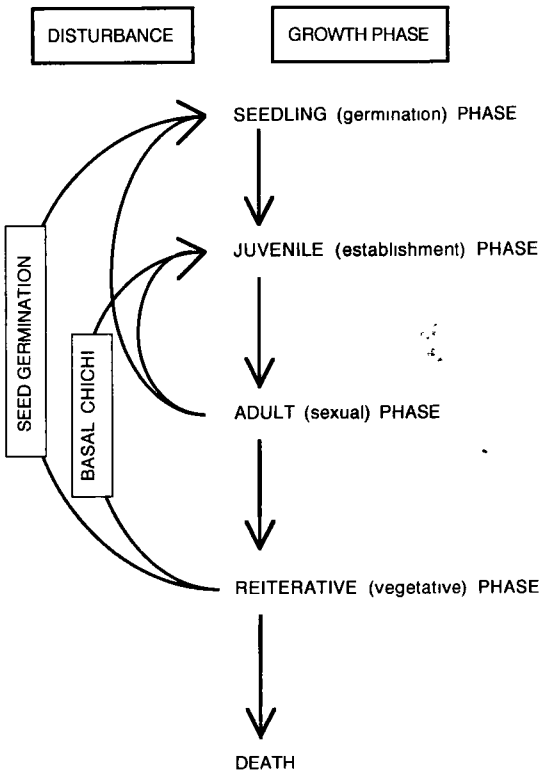

Figure 8 A schematic representation of the life cycle of Ginkgo biloba *on Tian Mu Shan.*

the origin of the *Ginkgos*. In this regard, however, Hui-lin Li has pointed out that throughout China such temple sites were initially selected because of their great scenic beauty, and that the forests surrounding them were secondarily preserved by resident monks—both Taoist and Buddhist. The fact that some of the large *Ginkgos* and *Cryptomerias* in the reserve were planted by humans should not be interpreted to mean that all of them were. Such guilt by association may be the cautious position, but it is not necessarily the correct one. Away from the paths, at elevations between 800 and 1,200 meters, there is little indication that the surrounding woods have been disturbed by humans, and the *Ginkgos* that are growing there, by virtue of their size and their multistemmed growth form, give the distinct impression of being wild.

The significance of the lack of *Ginkgo* seedlings in the reserve is also difficult to interpret. On the one hand it might be seen as evidence that *Ginkgo* is not native to the area, but on the other it can be viewed as evidence that *Ginkgo* does not reproduce from seed under the closed canopy conditions that now prevail on Tian Mu Shan. This latter suggestion is supported by the 1990 report on the "semiwild" *Ginkgo* population in Hubei Province, in which Jiang and his colleagues from the Wuhan Institute of Botany concluded that *Ginkgo* is a high light-requiring species and that seedling establishment occurs only in those portions of the forest where the canopy had opened up.

While it is difficult to answer with certainty the question of whether the *Ginkgo* population on Tian Mu Shan is "truly" wild, it is clear that the phenomenon of secondary trunk formation from basal chichi is an important factor in explaining the species' long-term persistence on the mountain. It is also possible that vegetative reproduction from basal chichi may have played a significant role in the extraordinary persistence of *Ginkgo* throughout geological time.

Acknowledgments

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