Ginkgos and People—A Thousand Years of Interaction

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Recent discoveries on the effects of *Ginkgo* leaf extract in promoting blood flow have stimulated renewed interest in this ancient plant.

Above all else *Ginkgo biloba* is a survivor, not only of the ravages of geological time, extending back at least 70 million years to the Paleocene, but also of the ravages of human time, the so-called Internecine. Indeed, the *Ginkgo* tree has a documented history of cultivation by the Chinese for close to a thousand years and an undocumented history that no doubt extends back much further.

As a result of this interaction, *Ginkgo biloba* has become so closely intertwined with human beings that its existence outside of cultivation has been the focus of an unresolved debate for over a hundred years. In the Western literature, Buddhist monks are widely credited with preserving *Ginkgo* from extinction by planting it in their temple gardens (Wilson, 1920), but little documented evidence supports this notion. The argument of H. L. Li (1956) that the tree was first cultivated for its edible and medicinally active seeds provides a more plausible, if somewhat less romantic, motivation for its preservation.

As a wild species in China, *Ginkgo* was probably a member of the temperate, mixed mesophytic forest that once covered the hill country bordering the Yangtze River valley for most of its three-thousand-kilometer length. Most of this forest has now been cut down except for remnants found in a few isolated valleys and on a few steep mountainsides (Wang, 1961). During the fall of 1989, the author and his colleagues, Professor Hsieh Ling of the Zhejiang Forestry Department and Guang Yang of the Nanjing Botanical Garden, visited one such area in eastern China, the famous Tian Mu Mountain in Zhejiang Province, where *Ginkgo biloba* still grows in a semi-wild state. Our ecological observations made on Tian Mu Shan indicate that *Ginkgo* is well adapted to growing on disturbed sites where light intensity is high, particularly along stream banks, on rocky slopes, and on the edges of exposed cliffs (Del Tredici et al., in press).

The purpose of this article, however, is not to examine the question of whether *Ginkgo* still exists in the wild but to examine the mutually beneficial interactions that have occurred between *Ginkgo biloba* and *Homo sapiens* over the last one thousand years. From the botanical perspective, these interactions have resulted in a tremendous expansion of the tree's range from its native Chinese home into every country in the temperate world. From the human perspective, the interactions

Figure 1. One of the largest Ginkgos *in Asia, growing on the grounds of Yongmun-san temple in Korea. The tree, about 60 meters tall and 5 meters in diameter, is reputed to be 1100 years old. Photograph by S. A. Spongberg.*

have yielded a beautiful ornamental tree that produces a nutritious food and a valuable medicine.

The Quintessential Survivor

Ginkgo is considered to be one of the toughest of all cultivated trees, a belief borne out by a famous specimen growing near the hypocenter of the 1945 atom bomb blast over Hiroshima, Japan. According to Michel and Hosford, the tree that still grows there today survived the bomb by sprouting from its base after its trunk was completely destroyed!

Another indication of *Ginkgo's* exceptional power of survival is its long life span. Throughout Asia there are many large and ancient specimens that are in excess of a thousand years old (Figure 1). (Miyoshi, 1936; Ling, 1965; Spongberg, 1978). According to Professor Ling of the Zhejiang Forestry Department, the largest and perhaps oldest *Ginkgo* in China is a specimen growing in Folaishan in Ju County, Shandong Province. It is an ovulate (female) tree, approximately three thousand years old, with a diameter at breast height (DBH) greater than 4 meters and a height of 26.5 meters. In Zhuji County, Zhejiang Province, the author saw one old ovulate tree with a DBH of 2.3 meters and a height of 33 meters (Figure 2). In 1988 this tree produced a remarkable 379 kilograms of cleaned nuts. If *Ginkgo* is indeed a pioneer species, as our work on Tian Mu Shan suggests, then it must be considered a *persistent pioneer* that can outlast several successional cycles.

Under cultivation, *Ginkgo* is considered highly adaptable, growing well in most parts of the temperate world with a distinct seasonality and moderate rainfall, including areas with a Mediterranean type of climate as well as those with a cold temperate climate, where the minimum winter temperatures can reach −30 degrees C. *Ginkgo* seems to grow best when planted in full sun, although it also shows the ability to persist indefinitely under conditions of low light, such as when planted along the cavernous, downtown streets of many cities in eastern North America.

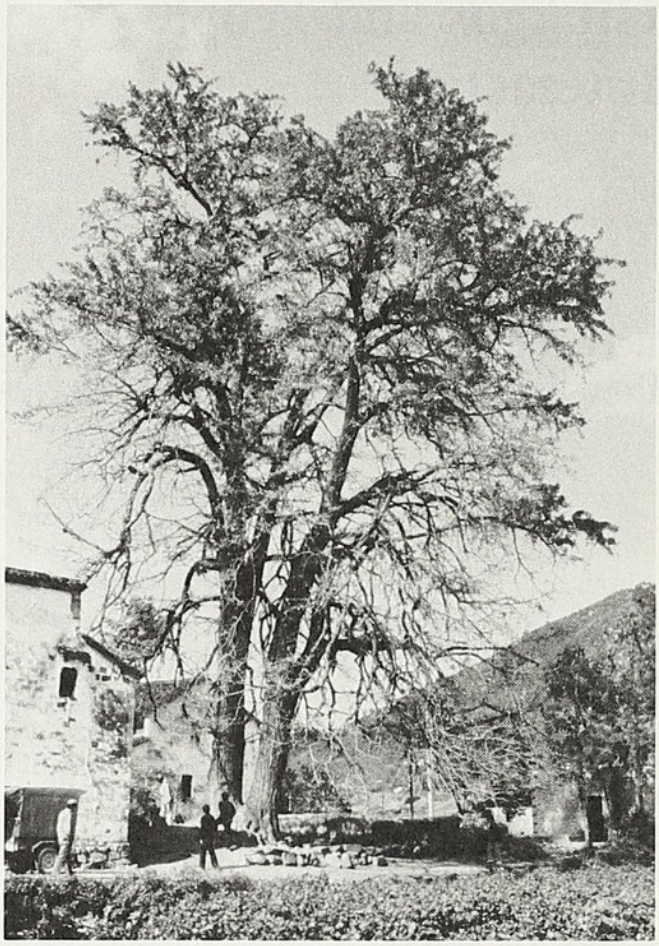

Figure 2. An ancient ovulate Ginkgo *growing in Yang Tang village, Zhejiang province. The tree had a diameter of 231 centimeters and was 33 meters tall in 1989. In 1988 the tree produced 379 kilograms of cleaned nuts.*

According to reports in the horticultural literature, *Ginkgo* will grow in a wide variety of soil types (with the exceptions of those that are very wet or alkaline or show a pronounced hardpan) but it prefers soils with a pH of 5.5 to 6.5. Under typical conditions of outdoor cultivation, the roots of most *Ginkgos* are infected by vesicular-arbuscular mycorrhizae (VAM) that play an important role in the uptake of the element phosphorus (Bonfante-Fasolo and Fontana, 1985; Fontana, 1985).

In addition to its great powers of survival, another characteristic that makes *Ginkgo* a particularly successful street tree is its high degree of resistance to insect damage and to fungal, viral, and bacterial diseases, relative to other cultivated trees. Contrary to the

numerous anecdotal reports, however, *Ginkgo's* tolerance of air pollution, particularly sulfur dioxide and ozone, is not that much better than other trees, and the tree is no less susceptible to damage from ionizing radiation than other gymnosperms (Major, 1967; Hepting, 1971; Sharma, 1989).

Under conditions of moderate soil fertility, *Ginkgo* grows quite rapidly, averaging up to half a meter per year when young. With the onset of sexual maturity, between 20 and 30 years, height growth generally slows down as the tree fills in its rather sparsely branched juvenile framework. At full maturity, *Ginkgo* is not a particularly tall tree, reaching a maximum height of about 30 meters, although one specimen in Korea has been measured at 60 meters (Figure 1) (Spongberg, 1978).

In the fall of 1989, I interviewed horticulturists in Shanghai, China, who worked for a division of the Ancient Trees Management Group of the Shanghai Public Garden Administration. They had catalogued and measured the height and girth of all the large *Ginkgos* in the province, and had found a total of four hundred trees over one hundred years old, half of which were over three hundred years old. They were willing to share their findings concerning the growth of *Ginkgo* only in qualitative terms, and told me that the growth rate in *Ginkgo*, measured in terms of centimeters of girth increase per year, is rapid and increasing between the ages of 1 and 40 years. Growth rate slows down between the ages of 40 and 110 years, and between the ages of 110 and 150 to 200 years, it is more or less constant. From 150 to 200 years and beyond, the growth rate of *Ginkgo* appears to diminish.

Cultivation in the West

Ginkgo was introduced into Europe from Japan at the Botanic Garden in Utrecht, Holland, about 1730, where a tree that is probably one of the original introductions is still in very good condition (Dallimore and Jackson, 1966). In Kew Gardens, England, a *Ginkgo* is still growing that was planted in 1754 and was probably part of the original introduction into that country. The first *Ginkgo* reported to produce fertile seed in Europe was a large male tree growing in the Botanic Garden of Montpellier, France, in 1835. This anomalous situation was brought about by the fact that scions from a female tree (growing near Geneva, Switzerland) had been grafted onto it some years earlier. This "hybrid" tree was still alive and in good health when the author visited the garden in 1990.

The first report of a *Ginkgo* growing in North America comes from a letter by William Hamilton of Philadelphia to his private secretary, Mr. Smith, who was in charge of his estate, Woodlands, in his absence. Writing from London on November 2, 1785, Hamilton admonishes Smith:

> The Cistus's the Heaths, eleagnus, Ginkgo, Laurus's, Tamarisks, Yucca glorioso, the Carolina mahogany, Zantoxylon sempervirens &c, should be secured by skreens of Dry straw or some other means, but by [no] means let dung be put to their Roots for it will inevitably kill them . . . (Smith, 1905)

While one staminate individual from this original introduction of *Ginkgo* was still alive and well in 1981, growing on the grounds of what is now the Woodlands Cemetery in Philadelphia (Del Tredici, 1981), the tree has since been cut down. Although there are no records to prove it, a large *Ginkgo* growing nearby in William Bartram's garden is thought to be a sibling of Hamilton's tree (Harshberger, 1920) and is now assumed to be the oldest *Ginkgo* in North America (Figure 3).

In the early 1800s, *Ginkgo* began to be grown in many parts of the United States, primarily in the private gardens of wealthy individuals. Remarkably, many of these early introductions are still alive and healthy. In 1841, the nurseryman and horticulturist Andrew Jackson Downing was among the first Americans to advocate the use of the *Ginkgo* as an ornamental:

> As the foliage is of that kind which must be viewed nearby, to understand its peculiarity, and as the form and outline of the tree are pleasing, and harmonizes well with buildings, we would recommend that it be planted near the house, where its unique character can be readily seen and appreciated.

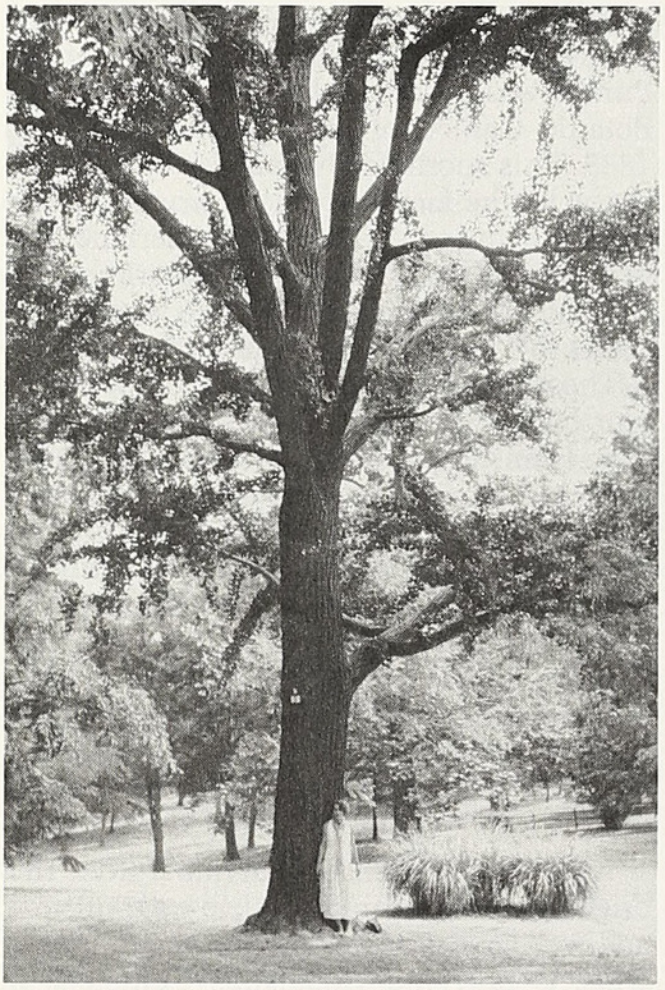

Figure 3. The Bartram Ginkgo, *presumably the oldest specimen in North America, planted circa 1784. When photographed in 1988, its height was 32 meters and its diameter at breast height was 103 centimeters.*

According to C. S. Sargent, the first *Ginkgo* to produce fertile seed in North America was a specimen growing on the grounds of the former Kentucky Military Institute in Frankfurt, Kentucky, in 1877. These trees were planted in the 1850s by Henry Clay, who, as an influential United States senator, had somehow acquired them directly from Japan (Del Tredici, 1981). Within the next ten years, many of the trees growing in Washington, D.C., were producing large quantities of seed, which were widely distributed to nurseries on the east coast (Falconer, 1890).

With the exception of a few saplings that came directly from Japan, it appears that most of the oldest *Ginkgos* growing in North America were imported from England as seedlings, which most likely had been raised from imported Japanese seed. By the late 1800s and early 1900s, after the original American introductions started producing seed in abundance, *Ginkgo* became popular as a street tree on the east coast, primarily in urban areas from Boston to Washington, D.C. (Corbett, 1903). Its tolerance of the particulate air pollution produced by burning coal was highly touted by horticulturists of the day, along with its high degree of resistance to fungal diseases and insect pests.

The horticulturist's love affair with the *Ginkgo* began to fade in the 1920s and 1930s when many of the widely planted seedling street trees began reaching sexual maturity. At this point, ovulate trees started producing large quantities of seeds, which, when crushed by passing foot traffic, resulted in a foul-smelling mess, reminiscent of the odor of vomit. In the horticultural literature, this scent is variously referred to as "disagreeable," "evil," "offensive," "disgusting," "repulsive," "nauseating," and "abominable." To make matters worse, the odoriferous sarcotesta contains anacardic acid, a compound known to cause a severe skin rash on those who happen to touch or walk barefoot on the seeds (Mitchell and Rook, 1979).

Vegetative Propagation

In response to the perceived litter problem posed by the production of seeds by female *Ginkgo*, Western horticulturists generally recommend the planting of vegetatively propagated male plants for street-tree use. Over the years, many male clones have been selected for this purpose, along with clones displaying a wide variety of distinctive leaf and habit characteristics (Santamour et al., 1983).

Most *Ginkgo* clones are remarkably easy to propagate vegetatively either from cuttings or by grafting. The author has had good success rooting cuttings of *Ginkgo* at virtually any time of the year, including: (1) softwood cut-

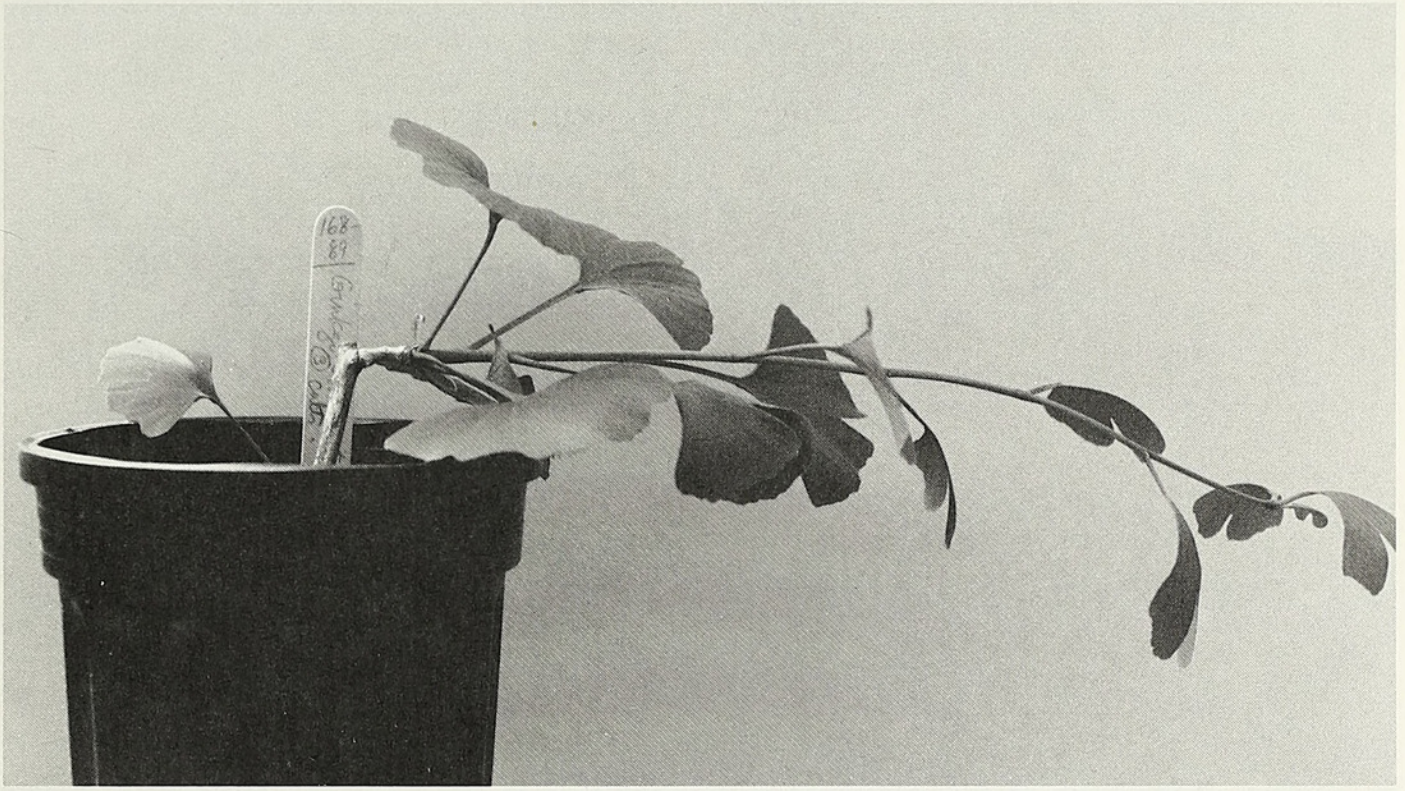

Figure 4. Topophytic effects in Ginkgo biloba. *This rooted cutting was originally collected from a mature tree in February 1989. The photograph, taken in May 1991, clearly shows the "fixed" horizontal orientation of new growth.*

tings collected in summer and placed under intermittent mist; (2) hardwood cuttings taken in the fall at the time of leaf drop; and (3) hardwood cuttings taken in the spring just prior to bud break. While treatment with indolebutyric acid (IBA) does not seem to be necessary in order to achieve a high percentage of rooting (Doran, 1954), there does seem to be some variation in the rooting response of different individuals, perhaps due to the age or vigor of the tree they were taken from (Vermeulen, 1960). Despite their high degree of rootability, *Ginkgo* cuttings usually grow slowly the first season following propagation, producing only rosettes of leaves and little extension growth. It is not until their second growing season that they will produce long shoots. For this reason most nurseries prefer to propagate *Ginkgo* by grafting scions of selected cultivars onto seedling rootstocks, a procedure that results in abundant extension growth during the first season of growth.

Although the preferential planting of male clones is widely recommended in the horticultural literature, one very important fact has made this goal largely unattainable: the vegetative propagations of *Ginkgo*, whether from cuttings or grafts, generally suffer from a developmental problem known as topophysis. Topophysis is defined as the organizational status of a meristem that is determined by its position on the plant and that remains stable through vegetative propagation (Hallé et al., 1978). In other words, if a lateral branch of *Ginkgo* is rooted or grafted onto a seedling rootstock, the resulting propagule will continue growing in the direction it maintained while it was still attached to its parent trunk (Figures 4 and 5). This means that vegetatively propagated *Ginkgos* seldom show the dominant central leader and whorled branch arrangement typical of seedlings. Instead, the branches grow out at erratic angles, producing low-branched trees with poor form from

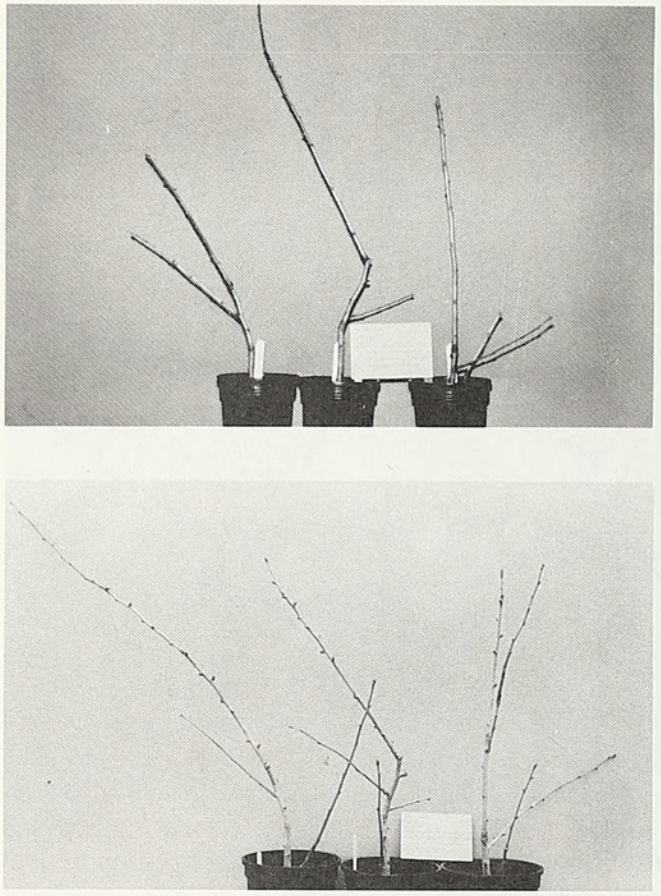

Figure 5. Rooted cuttings from a single branch of Ginkgo biloba *'Fastigiata' AA #144-39-A. Softwood cuttings were taken in August, 1981 and rooted under intermittent mist. (top) The two cuttings on the left were taken from diagonally growing lateral shoots, while the one on the right was taken from the vertical terminal shoot. Photographed in December 1985. (bottom) The same cuttings photographed in February 1991. For scale, the index card is 7 centimeters by 13 centimeters.*

the point of view of street-tree plantings.

The only way that nurseries have been able to circumvent the problem of topophysis is through the practice of "stooling" in which young stock plants are repeatedly cut back low to the ground to stimulate the production of numerous vertical replacement shoots. When these vigorous terminals are used as propagation material, they will produce a vertically growing tree. According to William Flemer of Princeton Nurseries, this technique seems to work particularly well with fastigiate (upright) clones of *Ginkgo* in which many of the laterals tend to possess a vertical orientation to begin with. At the present time such fastigiate trees are the only male *Ginkgo* selections that are widely available to the general public.

Cultivation for Nut Production

While Western horticulturists have concentrated on the ornamental uses of *Ginkgo*, Asian horticulturists have focused their attention primarily on the cultivation of the tree for its edible nuts. According to Dr. Frank Santamour and his colleagues (1983), Chinese horticulturists have selected at least 28 varieties based solely on the size and shape of the edible nut. *Ginkgo* nuts are highly nutritious and, when fresh, consist of 37.8 percent carbohydrate, 4.3 percent protein, and 1.7 percent fat (McCarthy and Matthews, 1984). While most of the carbohydrate is in the form of starch, small amounts of sucrose, glucose, and fructose are also present, giving the nuts a sweet taste.

When *Ginkgo* is cultivated for its edible nuts, the cultivar is generally grafted onto a seedling rootstock. As is the case with vegetatively propagated cultivars in North America, the grafted Chinese trees show strong topophytic effects (Figure 6). When the author was in eastern China during the fall of 1989, he visited Dongting Mountain on the shores of Lake Tai in Jinagsu Province. This well-known *Ginkgo* nut-producing area is the home of the famous cultivar 'King of Dongting Mountain,' which produces the largest nut of all *Ginkgo* cultivars (Figure 7). Old grafted trees in Dongting Shan were scarcely more than five meters tall and were branched low to the ground. They tended to lack both a central leader and whorled branches. While such a shape would be undesirable in a tree cultivated for ornamental purposes, it is considered advantageous in terms of nut production because it facilitates harvesting. This situation provides a clear example of the "domestication" of a plant by selective propagation.

In conversations with agriculturists who cultivated *Ginkgo* for its nuts in Zhuji Xian in Zhejiang Province, the author learned the

Figure 6. A grove of grafted Ginkgos *cultivated for their edible nuts on Dongting Shan, Jiangsu Province, China.*

following about the commercial production of *Ginkgo* nuts:

1. *Ginkgo* bears a heavy crop of seeds every other year, with relatively light crops in alternate years.

2. The grafted female trees produce nuts three to five years after grafting, as opposed to the twenty to thirty years it takes for seedlings to begin bearing.

3. In the older *Ginkgo* nut plantations, the male/female ratio was about 1 per 100. This ratio has been raised to 3 to 5 per 100 in recent times, leading to more effective pollination and greater nut production.

4. For successful pollination of female trees, the distance of the nearest male tree to the females is not as critical as (a) the size of the male tree—the taller it is, the better the pollination; (b) the direction of the wind—male trees should be planted upwind of females to achieve maximum seed set; and (c) the presence of barriers, such as buildings, which can inhibit the flow of pollen.

5. Seed production can be increased by manually placing branches of male trees within the crown of female trees during the time of pollination (Ling, 1983).

In China, the processing of the nuts for market is a very straightforward process. Either they are knocked off the trees in mid-September with long bamboo poles, or they are collected from the ground shortly after they fall. After collecting, they are allowed to sit for a few days in plastic containers, until the fleshy outer coat begins to soften (and smell). At this point the seeds are washed in running water so that the fleshy outer coat rises to the top and can be poured off, leaving the heavy nuts to sink to the bottom. It is imperative to wear gloves during this process since the fleshy coat contains anacardic acid, which causes a severe rash in many people.

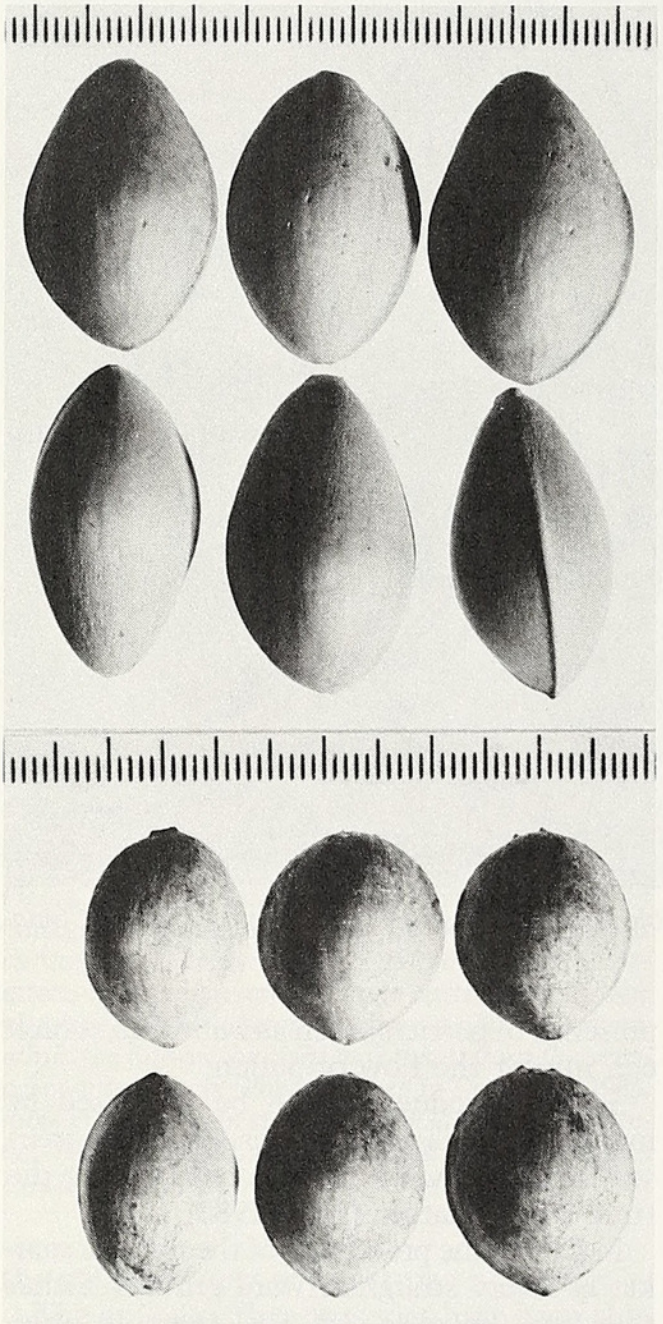

Figure 7. The exceptionally large nuts produced by the Ginkgo *cultivar 'King of Dongting Mountain' on the top, with a more or less typical* Ginkgo *nut on the bottom. Scale is in millimeters.*

After the seeds are washed, they are spread out to air-dry for one to two weeks, at which point they are bundled up and put in a cool environment for storage.

Raw *Ginkgo* nuts, which are rich in lipid compounds, are considered toxic to humans, and it is in this state that they are used in traditional Chinese medicine (Perry, 1980). For purposes of nonmedicinal consumption, the seed must be cooked. Usually they are boiled in water until the hard shell cracks open and the kernel can be removed. Traditionally either these kernels are boiled in sugar water to make a sweet soup or they are pan-fried and eaten plain. They can also be mixed in with other ingredients. The flavor and texture of the *Ginkgo* nut are reminiscent of the sweet chestnut, *Castanea sativa*. In several places I visited in China, I was warned not to eat more than seven *Ginkgo* nuts at one sitting; otherwise I would experience toxic side effects. Young children, in particular, are warned about eating too many *Ginkgo* nuts.

Because *Ginkgo* nuts are considered a delicacy throughout Asia, they sell for a considerable amount of money per kilogram. Most of the seeds that are produced in China are sold to foreign buyers, who, in 1988, paid 5 yuan per kilo (approximately $1.50). The price was depressed to 3 yuan per kilo in 1989 as a result of a lack of foreign buyers caused by the Tiananmen Square disturbances in the spring of that year.

Chinese living in other Asian countries are the principal consumers of the crop, although a substantial amount of seed is also shipped to Chinese population centers in Europe and North America. While the author was unable to obtain exact figures on total seed production for China, he was told that in 1984 the yield was more than 5 million kilograms of dried seeds.

Ginkgo as Medicine

The *Ginkgo* tree is apparently mentioned in the oldest Chinese herbal, *Shen Nong Ben Cao Jing*, dating from 2800 B.C. (Michel and Hosford, 1988). Specific reference to the medicinal use of the leaves, however, does not come until 1436 (in Lan Mao's *Dian Nan Ben Cao*), which recommends the *external* use of the leaves for treating skin and head sores, as well as freckles. The first mention of the *internal* use of *Ginkgo* leaves comes in 1505 in a text by Liu Wen-Tai, *Ben Cao Pin Hue Jing Yao*r. In modern Chinese medicine *Ginkgo*

leaf preparations are recommended as "benefiting the brain," as an astringent to the lungs, and to relieve symptoms of asthma and cough (Foster, in press).

Numerous pharmacologically active constituents have been extracted from the leaves of *Ginkgo*, such as flavones, biflavones, organic acids, and flavonoid glycosides, including kaempferol, quercetin, and isorhamnetine. It is the diterpene lactones, however, including ginkgolides A, B, C, J, and M, and the sesquiterpene, biloablide, that have aroused the most interest and have been the focus of most modern research. A, B, and C are found both in the leaves and the "bark" (cortex) of the root, while J is found only in the leaves and M only in the root cortex (Boralle et al., 1988).

The ginkgolide compounds are unique 20-carbon cage molecules that possess an electron-rich cavity ideally suited for the binding of cations or polarized molecules (Figure 8). Recently, Professor E. J. Corey and his colleagues at Harvard University have synthesized ginkgolide B under laboratory conditions, but the prohibitive cost of the procedure makes it unlikely that a synthetic product will ever replace the natural extract.

The ginkgolides also show varying degrees of potency as specific antagonists of platelet-activating factor (PAF), a compound identified as a crucial mediator of a wide range of physiological processes and pathological conditions. Of the five naturally occurring ginkgolides, B is considered the most active from the point of view of antagonizing PAF (Braquet, 1988, 1989).

Numerous pharmacological and clinical studies with *Ginkgo* leaf extract have demonstrated a positive effect in increasing vasodilation and peripheral blood-flow rate in the capillaries of patients suffering from a variety of circulatory dysfunctions. In Europe, the *Ginkgo* leaf extract is most popular among the elderly, who take it either to treat the minor symptoms of aging, such as dizziness, ringing in the ears, and short-term memory loss, or to treat the side effects of major disorders, such as Alzheimer's disease. In one series of

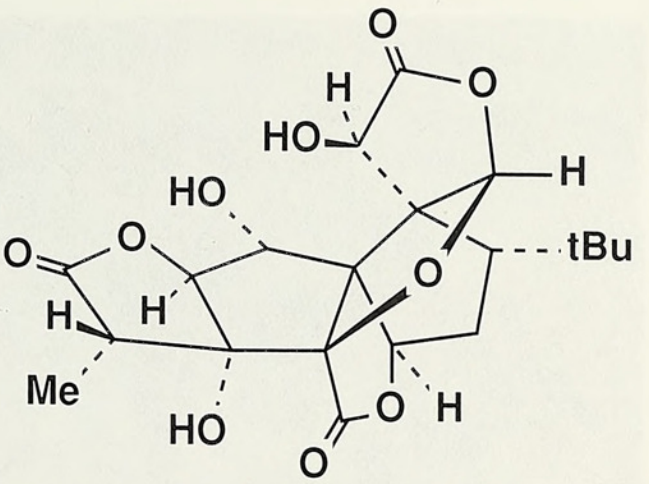

Figure 8. The chemical composition of ginkgolide B, a unique 20-carbon cage molecule with a tert-butyle group (tBu) and methionine (Me) incorporated into the framework. The electron-rich cavity, formed by the three lactonic groups (–OC=O), is ideally suited for the binding of positively charged cations.

tests, *Ginkgo* extract has been shown to increase short-term memory function in both healthy, young volunteers and elderly patients suffering from vascular disorders (Hindmarch, 1988).

Positive results with the extract have also been achieved in the treatment of the inflammation of the bronchial airways associated with asthmatic attacks. The extract was more effective in the treatment of asthma when administered directly into the lungs as an aerosol rather than taken orally (Roberts and Barnes, 1988).

Ginkgo leaf extract has also been proven effective in the treatment of arthritis, airway hyperactivity, thrombosis, endotoximea, poor blood circulation, and gastrointestinal ulceration. It has also been shown to be useful in the treatment of various eye, ear, and skin diseases. After nearly fifteen years of clinical trials in Europe, there are no reports of toxic side effects.

Ginkgolide Cultivation

Ginkgo has been cultivated specifically for the purposes of leaf production for ginkgolide extraction since 1982, when large-scale plantings were established in Bordeaux, France, and

Figure 9. The Ginkgo *plantation in Sumter, South Carolina, in early spring. For scale, the individual segments of the irrigation system are about 45 meters long.*

in Sumter, South Carolina. Seedlings are planted 40 centimeters apart in rows one meter apart, comprising a stand of approximately 25,000 trees per hectare. For the 400 hectare (1000 acres) plantation in Sumter, this amounts to an amazing 10 million *Ginkgos* —surely the largest *Ginkgo* forest on earth, at least since the Paleocene (Figure 9).

In Sumter, the leaves are harvested from mid-August to mid-September while they are still bright green, and the resulting yields are between 3,000 to 4,000 kilograms of dried leaves per hectare (2,640 to 3,520 pounds per acre). The trees are severely pruned in the winter following the harvest to induce multiple branching and to keep the plant small enough to make it possible to harvest the leaves mechanically (Figure 10) (McClintic, 1991).

Freshly havested *Ginkgo* leaves have a moisture content of about 75 percent. Moisture is reduced to 12 percent by passage through a gas-fired, 15-meter-long rotary drum drier. The dried leaves are then compacted into 180-kilogram bales, wrapped in burlap and polyethylene, and then loaded into containers and trucked to Charleston, South Carolina, where they are loaded on a ship that takes them to extraction plants in Europe.

In Europe, the extract is marketed under the brand names "Thebonin,©" "Tanakan,©" and "Rökan,©" and gross annual sales in 1988 amounted to about $500 million (Corey et al., 1988). While the use of *Ginkgo* leaf extracts has proved to be very popular both in Asia and in western Europe as a prescription drug, the product has yet to be marketed to any great extent in the United States. This unavailabil-

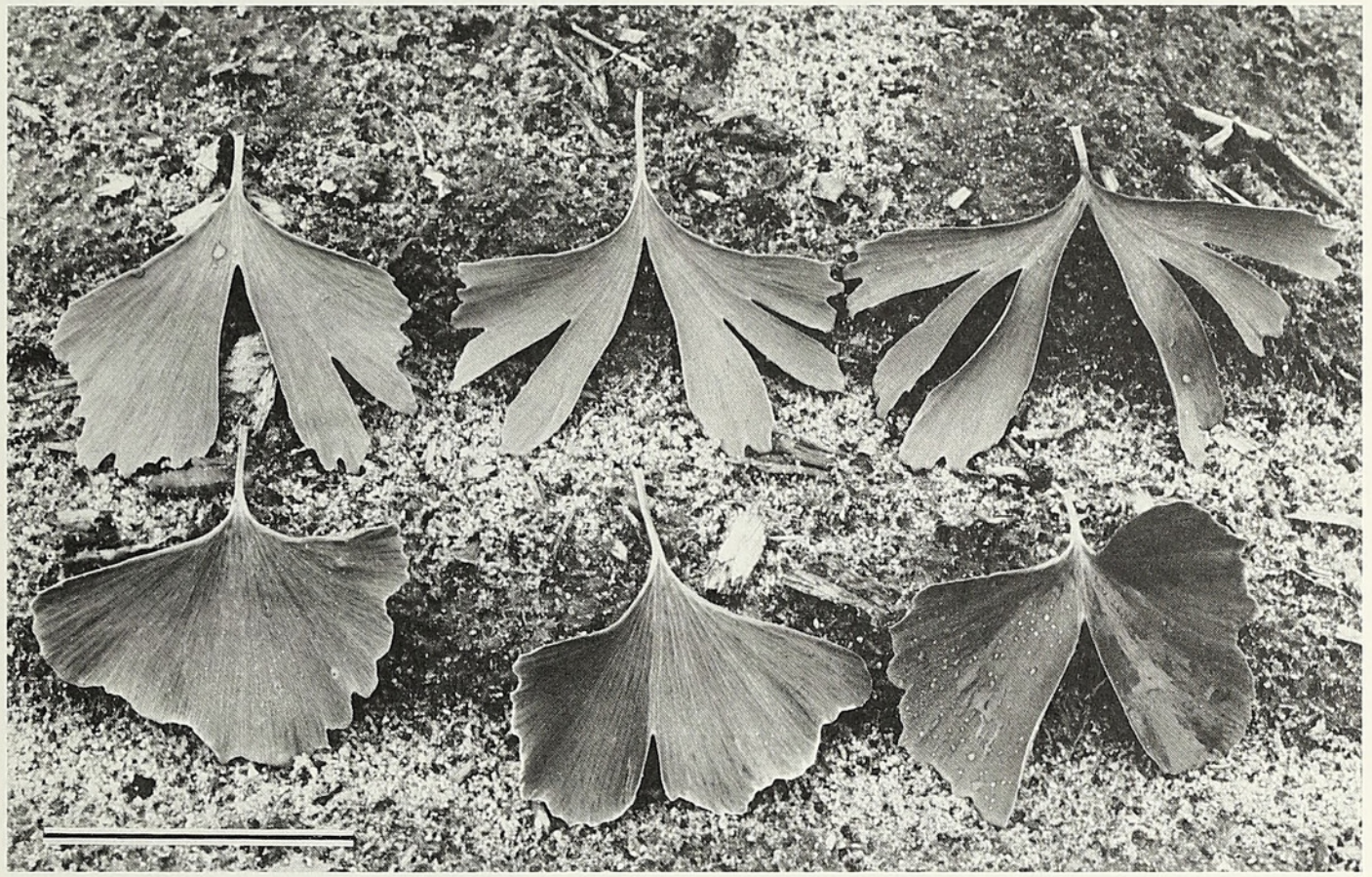

Figure 10. Some of the highly variable, and exceptionally large, leaves produced by the heavily fertilized Ginkgos *growing on the plantation in Sumter, South Carolina. Scale bar at the lower left is 10 centimeters long. Some leaves are so highly dissected that they might almost be considered compound.*

ity is primarily due to the fact that the extract does not meet the purity standards of the United States Food and Drug Administration for prescription drugs. As a result, the extract is only available in health food stores as a rather expensive herbal remedy. It is sold under a wide variety of names, but mainly these products are just a repackaging of the products produced in Europe. At this point, it is unclear if *Ginkgo* leaf extract will ever receive FDA approval as a prescription drug available to consumers in the United States.

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