Native tapping trees of *Hevea guianensis* during the years of the Second World War, when wild rubber stands of the Amazon helped to replace plantation production interrupted by the Japanese occupation. R. E. Schultes photo.
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BOOKS
The Tree that Changed the World in One Century

Richard Evans Schultes

I can assure you that on that 14th of June (1875) when Mr. Wickham arrived at Kew in a hansom cab with his precious bags of seeds, not even the wildest imagination could have contemplated its result... 

— Sir W. T. Thiselton-Dyer
Kew Bulletin (1912), p. 65

History is usually written in the context of political, social, or religious changes. Yet it might well be written from the point of view of the effects that plants have had on the development of mankind and civilization.

It is safe to say that no single species of plant has, in the short space of 100 years, so utterly altered lifestyles around the globe as Hevea brasiliensis, a member of the spurge family, which today is the source of 98 percent of the world's natural rubber. Stop for a moment and try to imagine life without rubber!

The introduction of this Amazonian tree from the wild and its domestication in the 19th century was the work of the British botanical gardens, especially the Royal Botanic Gardens at Kew, and is unquestionably the most outstanding example of the value of such institutions in bettering life on earth.

Rubber-yielding trees and vines grew in the Old World, yet, curiously, no significant use of their product had been made anywhere in the Eastern Hemisphere. When Columbus arrived in the West Indies, he noted that the natives were playing a game in which rubber balls were employed, but the rubber for these balls came not from Hevea but from Castilla elastica, of the fig family.

As early as 1755, King John of Portugal tried to foster a rubber industry in Belém do Pará at the mouth of the Amazon River: rubber shoes were manufactured for export to Portugal, but the quality was so poor that the industry did not prosper. The process of vulcanization, which has made rubber the useful product that it is now, had not yet been discovered.

After Goodyear discovered vulcanization in the 1830s, rubber became a product with ever-increasing uses in the industrializing nations, and demand for it increased at a vertiginous rate. The only source was the wild stands of Hevea — especially H. brasiliensis — hidden away in the dark corners of the vast Amazon forests. The demand for rubber in Europe and the United States rapidly became so great that production from forest trees rose from 31 tons in 1827 to 2607 tons in 1856. This dramatic increase was accomplished by the virtual enslavement of whole tribes of Indians. Tapping the trees in the jungles for four or five months a year, away from their agricultural lands and sources of...
nourishment, falling prey to tropical diseases and malnutrition, and often suffering from exposure, mistreatment, torture, or even assassination if they did not bring in enough rubber, they were being exterminated by this forest industry, directed primarily by unscrupulous “rubber-barons” who resided in the cities of Manáos and Iquitos, usually in sumptuous luxury.

The modern age of rubber had its beginnings in 1876, a “rubber revolution” that was the consequence of an incredible series of sometimes fortuitous events. *Hevea* became known to the scientific community when in 1775 the French botanist J. B. C. F. Aublet described the genus from material collected in French Guiana. He not only described the genus and its first species, *H. guianensis*, but detailed the native method of exploiting it for rubber and appended numerous ethnobotanical data on the use of the seeds by the natives as food. Twenty-six years later, K. L. Willdenow, a German botanist, described a second species, *H. brasiliensis*, from material collected at the mouth of the Amazon River. Subsequent botanical exploration of the Amazon Valley — notably that carried out
by the British botanist Richard Spruce — continued to add new species to the genus, which now comprises 10 species and three varieties.

Not all of the species yield a latex capable of producing rubber: only *H. guianensis*, *H. benthamiana*, and *H. brasiliensis* have sufficient caoutchouc to give a usable rubber; and of these, *H. brasiliensis* supplies the best product.

When in 1823 a Scot, Charles Macintosh, discovered that rubber would dissolve in naphtha, it acquired many new uses, leading to the establishment of factories in England, France, and the United States. These factories failed, however, because the product still became sticky in the heat and brittle in the cold.

This problem was overcome in 1839 when a Bostonian, Charles Goodyear, discovered vulcanization, a process that greatly altered the physical properties of rubber and changed the history of the significance of this vegetal product and its effect on human life. It led immediately to new and hitherto unexpected applications and a host of new industries. It also sparked the “rubber boom” of the Amazon, then the only source of natural rubber: production from the South American forests rapidly increased.

Exploitation of wild rubber is a difficult and frustrating operation. The natives, living during the tapping season under such abominable conditions, produced a poor-quality product. The latex was frequently laden with bark, dirt, and stones and adulterated with other rubbers, since often the tappers were punished if they did not procure stipulated quotas. Furthermore, each individual had to labor from dawn or predawn until nearly noon to tap 100 or fewer trees in his forest circuit, then return to his shack and begin the long process of coagulating the latex. Large balls of rubber were formed by pouring the latex little by little over a pole that was rotated in smoke rising from an inverted funnel.

The death knell for this primitive industry was sounded when the era of scientifically managed plantation practices began in 1876, the year that rubber seeds were first germinated successfully in the Royal Botanic Gardens at Kew. The domestication of the rubber tree served civilization in two ways. First, it provided an abundance of high-quality rubber at low cost, without which many of our great advances in industry, medicine, domestic appliances, and transportation would have been impossible. Second, when plantations finally came into full production in the second decade of the 1900s, the forest industry was all but obliterated, with the result that thousands of native tappers were liberated from the intolerable and inhuman exploitation to which they had been subjected for nearly 100 years. And, undoubtedly, whole tribes — e.g., the Witotos of the northwestern Amazon, a truly noble race of Indians — were saved from virtual extinction.

Domestication of the rubber tree occurred at the time the British were seeking new crops for their tropical colonies. The introduction of the quinine-bark tree into India from the Andes had just been highly successful. Sir Clements Markham, who had directed the introduction of that tree, was convinced that the rubber tree could be developed as a plantation crop that would be a good substitute for the coffee crop, which a fungal disease had almost exterminated in Asia. He had Mr. James Collins prepare a summary of what was then known about
rubber. Collins wrote: “In 1870, I came to the conclusion that it was necessary to do for the caoutchouc-producing tree what had already been done with such happy results for the cinchona (quinine) tree.” Sir Joseph Hooker, director of Kew Gardens, knew of Spruce’s discoveries and studies of Hevea in the Amazon, and he fully supported Markham’s view concerning the future of Hevea cultivation.

Several earlier attempts had been made to introduce Hevea seed from Brazil, in 1873 and 1875. None were successful. Hevea seed, its latex rich in sugars, quickly ferments in the heat of the tropics, and the embryo is killed. But success eventually came.
An Englishman, Henry Wickham, who had spent many years living near the Amazon and Orinoco and who in 1872 had published a book on his travels in tropical South America, had previously sent seeds of *Hevea* to Kew with no success. Fully realizing that earlier shipments had failed because of slow transport, Wickham resolved somehow to surmount this difficulty. Then a fortuitous event happened! In 1876 a steamboat from England had sailed up the Amazon laden with cargo; it found no return load. “I determined,” Wickham wrote, “to plunge for it. I had no cash on hand. The seed was even then beginning to ripen. I knew that Capt. Murry must be in a fix, so I wrote chartering
the ship." Wickham sent out his Indians to collect the seed and pack it properly in wicker baskets. The ship raced downstream from Santarém, 400 miles up the Amazon, and called in at customs in Belém at the river's mouth. Customs officials, told of the delicacy of the plants "for delivery to Her Britannic Majesty's own Royal Botanic Gardens of Kew," immediately, and with intelligence unusual among bureaucratic officials, dispatched the ship, which steamed off to England.

All of the earlier shipments had been sent on sailing vessels. The few days saved by using a steamboat ensured successful germination in Kew's hothouses. Of the 70,000 seeds, 2800 germinated — a rate of 4 percent, astonishingly high for *Hevea*, even in the field.

Young trees from this introduction were sent to Ceylon, where several of the original trees still are living in botanical gardens. From Ceylon some went to Singapore and other parts of the empire in the tropics. The domestication of this tree, which has in one century so drastically changed life around the world, would not have been possible without a chain of botanical gardens and a far-sighted director at Kew like Hooker.

In Brazil stories are rife concerning the British "seed steal." At that time Brazilian law permitted the exportation of seeds, and collection and exportation were carried out openly. Many Brazilians are persuaded to believe that rubber seeds were "stolen" or "smuggled" out of the country, however, and fail to realize that Brazil's major agricultural industries are based on plants introduced from foreign countries: coffee (originally from Abyssinia), rice (from India), sugar (from Southeast Asia), soybeans (from China), jute (from India), cacao (from Colombia and Ecuador). In fact, most of the world's principal plantation crops are produced in regions far from their original homes.

When the Brazilians realized that the British plantation efforts were to be successful, they prohibited further exportation of

The oldest tree of *Hevea brasiliensis* in Malaysia, from one of nine seeds planted in 1877. Photograph courtesy of Rubber Research Institute of Malaysia, Kuala Lumpur.

Henry Nicholas Ridley examining one of his early experiments in tapping systems of *Hevea brasiliensis*, Malaysia. Photograph courtesy of Rubber Research Institute of Malaysia, Kuala Lumpur.
rubber seeds, and that prohibition held until very recently. Consequently, the vast rubber plantation system of the Old World was based primarily on these original seeds, which were collected from a single locality and from a single [and not the most promising] ecotype of Hevea brasiliensis. It is believed that the 70,000 seeds came from 26 original trees. In view of this, the enormous improvement in the commercial rubber tree in the space of 100 years seems incredible. The earliest plantation set out in Ceylon yielded 400–450 pounds of dry rubber per acre per year; there are new clones of the rubber tree that now yield more than 3000 pounds, and, with a recently developed chemical treatment of the bark, some clones may almost double that amount.

Many names of major importance are connected with the historical accomplishment of domesticating a wild tree of the humid Amazon. These include Aublet, Spruce, Macintosh, Goodyear, and Wickham, mentioned earlier. But Wickham and two others — Ridley and Cramer — were perhaps all-important in the creation of the great plantation industry that supplies the world with more than 98 percent of its natural rubbers. Wickham, who lived to a venerable old age, was rightfully knighted in the late 1920s for his part in the creation of the rubber industry.

Henry N. Ridley was appointed director of the Botanic Gardens in Singapore in 1888. It was my unexpected good fortune in 1950 to spend several days chatting with Ridley in his 95th year. He lived near Kew Gardens and was overjoyed to review some of his hopes, his trials, his successes in the early history of rubber in the Far East with a young botanist who was studying the numerous species and their ecotypes in the wild in South America. It was during these personal exchanges that I realized that Ridley was in fact one of the major founders of our modern rubber plantation industry.

When Ridley took up his position, he found only nine original trees and some 1000 young plants left from the original introductions to the Malay Straits in 1877. He immediately raised 8000 more plants from seed imported from Ceylon. These trees, from the original Wickham stock, became the mother trees of much of the rubber that eventually covered a large portion of Malaya.

Next Ridley began his celebrated experi-
ments on tapping methods. At that time trees in the Amazon were slashed according to a great variety of makeshift techniques, frequently to the detriment of the tree. The most prevalent method involved the use of the "machadinho" — a small ax used to make deep incisions in vertical lines up and down the trunk, causing eventually enormous hypertrophied tumors, which later prevented efficient tapping.

Ridley tried cutting off very thin layers of the bark with a sharp knife in a sloping channel, avoiding injury to the cambium, since in *Hevea* all of the latex-bearing vessels are external to the cambium. He began with the well-known herring-bone method and recommended infrequent tapping to allow the trees to rest. Eventually, he learned that more frequent tappings would not harm the tree and abandoned the herring-bone system and cut in slopes from right to left, since cuts in this direction were shown to give higher yields. Among numerous other discoveries, he experimentally showed the advantages of tapping done in the morning rather than the afternoon.

Ridley's advances, perhaps more than any other, assured success of the Asiatic plantation industry. By 1897 all tapping in Asia was based on Ridley's scheme of reopening the wound. The sudden increase in world demand for rubber further stimulated research into efficient and higher-yielding tapping techniques, in all aspects of which Ridley took part. His experiments led eventually to the spiral system of tapping, which today is nearly universal in plantation practice.

Ridley made another significant contribution to the rubber industry of the future in his campaign to establish rubber as a plantation crop. A series of events led him to this: a serious fall in the world price of tea, the devastating fungal disease of *Coffea arabica*, and poor results with cacao. Another factor was the increasing use of the automobile; automobile tires gradually became the greatest single consumer of the product. Ridley seized the opportunity, and soon planters were establishing rubber.

Again it was my good fortune in 1950, when Dr. P. J. S. Cramer was retired in Utrecht, Holland, to spend three days chatting with *oude Piet* ("old Pete"), as the uni-
When I started in 1888 in an attempt to cultivate rubber for profit, it was com- paratively little used so that it is today, and so what it will be in the future.

In calculating the amount that would be required in 1900, I calculated for bicycle-tires, the poor man's carriage, luxury auto tires, for motor vehicles as they were hardly invented and I thought they would only be a rich man's toy for many years. However we (I and my one assistant) were ready for all eventualities in time for the boom.

I shall be very interested in your discoveries. When you publish them, your literature of your programme has not come to hand yet. I look forward to its arrival. I should like to see the photographs of the dwarf variety you mention. It must be a very curious plant.

My wife sends her warmest greetings to you and I too wish you the greatest success and happiness in your work in Colombia.

Yours sincerely,
Henry B. Ridley
versity students affectionately called him. We reviewed the initial introduction of *Hevea* stock to the Dutch East Indies from the British Malay Straits — material derived from the original Wickham seeds — and his early successful efforts to introduce from South America seeds of several other species of *Hevea* for eventual genetic studies. He told me about the difficulties he experienced in attempting to convince commercial developers that the planting of seeds (instead of using clonal material) was not the best way of establishing plantations of rubber trees. In these three days we experienced a remarkable camaraderie based on our very divergent experiences with *Hevea*, and I acquired an abiding understanding of the difficulties encountered by these pioneers: Ridley and Cramer.

When the Dutch had established a plantation crop from material originating in Penang, Malaysia, Cramer carried out the first variation analyses on *Hevea brasiliensis*. These early studies indicated that the species is extremely variable, especially with respect to yield of latex, an important commercial consideration. Through his analyses Cramer demonstrated the impossibility of predicting yield of rubber from plantations established on seed material, mainly because of cross pollination. He predicted that vegetative selection, cloning, and generative selection or breeding would lead to improvements in yield. All his predictions proved true. Cramer’s studies led to the eventual vegetative reproduction of high-yielding clones, which today is basic to all rubber-plantation practice.

Letter to the author from Henry N. Ridley in his 95th year.
A modern plantation of *Hevea brasiliensis* in Malaysia. Photograph courtesy of Rubber Research Institute of Malaysia, Kuala Lumpur.
Latin America on life on the Amazon during the rubber boom. The title, *La Voragine (The Vortex)*, refers to the belief that the jungle mysteriously swallows up the rubber tappers. One magnificent passage describes the almost fearful worship of the rubber tree in those days: "I have been a rubber tapper. I am a rubber tapper. I have lived in the muddy swamps in the solitude of the forests with my crew of malaria-ridden men cutting the bark of the trees that have white blood like that of the gods."

If we consider the changes for the good of mankind that "white blood" brought about when the rubber tree was finally domesticated, perhaps we might agree that it was actually blood of the gods!

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### Selected Readings


Richard E. Schultes is Jeffrey professor of biology and director of the Botanical Museum of Harvard University.
Have you ever wondered why one introduced species within a genus flourishes in the nursery and landscape industry while a native American plant with notable traits remains obscure? An example of this occurs in the genus Cotinus. Cotinus coggygria Scop., the common smoke tree or smoke-bush, whose native range extends from South Europe to Central China, is frequently seen in residential landscapes here. It is sought after because of its many fine qualities: a long period of midsummer floral and fruit ornamentation, showy plumose fruit panicles (which create the smokelike effect that gives the plant its common name), vivid autumn foliage colors, ease of culture, and longevity (the oldest plants extant at the Arnold Arboretum are 108 years old and healthy). Our native American smoke tree, C. obovatus Raf., on the other hand, is rarely seen. It is often missing even in the horticultural literature. Older books on landscaping omit it completely. When it is included, it is described in almost disparaging terms: “the fruiting panicles are not showy — it is useful only for autumn color — where the smaller smoke tree will suffice, the American species can be omitted.” Writers always attempt to compare the American species with its Asian relative. We have observed fruit panicles in the wild that are quite showy, though it is fair to say that those on the Arboretum’s trees are not. We shall lay comparison aside here and give our native species the attention it deserves.

Robert A. Vines, in his book Trees, Shrubs and Woody Vines of the Southwest, states that Cotinus obovatus occurs on “rocky limestone hills of Texas, Oklahoma, Arkansas, Missouri, Alabama, Tennessee and Kentucky. Nowhere very abundant or widespread.” Thomas S. Elias, in Trees of North America, says that it generally grows in limestone soils of dry, rocky slopes, in mountain canyons, or on high hills. It is found at elevations up to 1000 m. Because it inhabits locations with hot humid summers and relatively mild winters, many assume that it will not thrive under the soil and climatic conditions of northern landscapes. Yet we have found a planting as far north as the Landscape Arboretum at the University of Minnesota. Dr. Harold Pellett, on the staff there, told me that the arboretum had had success with seed of a cultivated plant from the Morton Arboretum in Lisle, Illinois, in 1963. Today, one of the resultant seedlings, which grows in an exposed site, is nearly 5 m tall. It is stem hardy at temperatures above approximately −25°F. The minimum temperature at which the roots are cold hardy has not yet been determined. Information on the original native locale of this plant is unavailable. A more cold-hardy genotype may yet be found.

A second welcome feature of the Ameri-
ican smoke tree is its adaptability to various soil conditions. In Tennessee it occurs on south-facing rock outcroppings of limestone, where the pH is 6.5 to 7.0. Very little soil is present on top of the rocks, so the roots must invade the cracks and crevices to anchor the plant and obtain moisture and nutrients. In the same area it also grows in sites with better soil, where it associates with Juniperus virginiana, Rhus aromatica, Viburnum prunifolium, Cercis canadensis, and Quercus prinoides. At the Arnold Arboretum a 102-year-old specimen flourishes in highly acidic soil near the edge of a meadow. Peter Del Tredici, of the Arnold Arboretum staff, observed the plant thriving in alkaline clay soils in the Chicago area. Excess soil moisture, however, may detract from optimum autumn foliage coloration.

The relatively low stature (8 to 12 m) of this tree makes it suitable for small or crowded landscape sites, where it can serve as an alternative to dogwood, crabapple, and hawthorn.

The fall-foliage colors of this tree are stunning. At the Arnold Arboretum few plants match it in terms of brilliance and intensity. In full sun the colors are scarlet, orange-scarlet, and claret and in shade apricot, gold, and yellow. A. C. Downes acclaimed the plant for its fall colors in 1935 in The Gardeners’ Chronicle: “seen with the autumn sun shining through its translucent leaves, decked out in all shades of flaming orange and scarlet, it has been a sight not easily forgotten... It is just the translucent quality of its foliage that causes the warm fiery glow that is its great charm. Other plants can show colors as vivid in themselves (as, for example Rosa nitida), but their thicker leaf blades rob them of the wonderful effect...”

Soil moisture and soil nutrition seem to affect autumn brilliance. One writer suggested that when grown on rich soil that is high in nutrients, the resultant lush, soft growth produces poor fall color. A. J. Anderson, in a 1945 issue of The Gardeners’ Chronicle, said “the most beautifully colored examples I have seen are growing on an exposed, dry bank of poverty stricken soil. A moist, rich medium should definitely be avoided as it always results in vigorous, sappy growth which is detrimental to autumn coloring.” Fall weather also seems to affect color brilliance. At the Arnold Arboretum one plant varies from very colorful to dull depending on sunlight and temperatures in early October. In the wild, autumn color varies substantially from one plant to the next.

Emerging spring leaves exhibit colors from soft bronze to purple, which are particularly attractive with backlighting, which exposes the sparse hairiness of the leaf surface. Summer color of fully expanded leaves is a dark green.

The bark of the American smoke tree provides pattern and detail in the winter landscape. Bark plates have bases lifted slightly and pulled away from the stems, creating a fish-scale-like effect. The scale pattern varies among individuals, and the plant could benefit from selection for this characteristic. Plants must reach approximately 20 years of age before the mature bark pattern develops. At this point the plant can be pruned to expose the bark to view. The bark can be an interesting focal point of a winter landscape. The tree can also be planted en masse to

A 102-year-old American smoke tree (Cotinus obovatus) at the Arnold Arboretum. Barth Hamberg photo.
create a mini-forest of textured stems.

Cut logs of the American smoke tree match *Juniperus virginiana* in durability and longevity and have been used as fence posts and walking sticks. When the tree is cut for logs or burned over by fire, the stump has the ability to resprout quickly, resulting in multistemmed specimens. As a result, most wild plants are multistemmed and not very straight. Color on freshly cut wood samples varies from bright yellow to pale orange. Extract from the wood was an important source of a natural dye, especially during the Civil War period.

Flowers and fruit are borne in large terminal panicles. Attached to the upper end of each panicle are slender stalks clad in fine hair. These create the smokelike effect, which in the wild varies in color (from light brown to fleshy tones and pale purple), size, and density. The sexes occur usually on separate plants but occasionally on a single plant. In the horticultural literature the male plant is reported to be superior for "smoke production." All of these factors suggest that selection could produce a more beautiful tree. Fruiting is said to be sparse in the wild. Seed is often difficult to find, as squirrels gather it before it ripens.

The height of the plant varies considerably, though this may be attributable to environmental conditions. The largest plant documented is a national champion tree at the Deane Hill Country Club in Knoxville, Tennessee. The tree is 13 m high, with a crown spread of 10 m, and a trunk girth of 1.5 m. The oldest and largest plant at the Arnold Arboretum came from seed sent by Charles Mohr of Mobile, Alabama, in 1882. As of February 1984 this plant stands 9 m
tall, with a crown spread of 8 m and 5 stems arising from ground level, of which the largest two are 45 cm in circumference. In poor soils and under harsh environmental conditions in the wild, the plant can be found in spreading thickets free of other species. Such varied growth habits allow great opportunity for the selection of individuals for specific purposes.

**Growing the American Smoke Tree**

Vegetative propagation is successful in early summer. Cuttings are taken just before the new season's growth begins to harden, and the soft fleshy tip of each cutting is pinched off. They are trimmed to 15 or 20 cm long and dipped quickly in I.B.A. in methanol or treated with Hormodin Number 3. They are then planted outdoors in ground beds covered with plastic tents and protected with 47 percent shade cloth. The cuttings are misted for 15 seconds every 15 minutes. This watering regime is critical, for if mist is maintained too long cuttings rot

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The common smoke tree (*Cotinus coggygria*). Pamela Bruns photo.
and quickly deteriorate. As soon as the cuttings begin to root, mist is reduced and then discontinued, and the plastic removed. The cuttings should be allowed to dry out between waterings. Rooting can take place in as little as 16 days but typically requires 4 to 6 weeks. When cuttings resume growth in early spring, successive crops can be taken for quick stock increase.

By the end of the first growing season, the rooted cuttings are 0.6 m tall. By the end of the second year, after transplanting and pruning, multiple-branched specimens can reach 1 to 1.5 m tall. If the plant is to be grown as a standard, all but the most vigorous branches must be removed.

In autumn plants should be subjected to one or two light frosts and then covered before temperatures reach the low 20s. Water and moisture in winter storage need careful attention as the plants are vulnerable to rotting. Rooted cuttings, as well as larger plants, transplant easily. Both need to be tested for container growing. These trees hold great promise for use in raised and streetside planters, as they thrive in the most harsh environments in the wild.

Seed propagation does not seem to be viable on a commercial scale, for the seed crop is usually unreliable. However, hobbyists and plant breeders should attempt crosses between *Cotinus obovatus* and *C. coggygria* in search of superior garden forms.

Peter Drummer, a propagator at Hillier Nursery in England, has hybridized *Cotinus coggygria* 'Velvet Cloak' with *C. obovatus*. Drummer plans to show superior seedlings at the Royal Horticultural Society show in London, after which the best will be named. The characteristics making Drummer's plants distinct are flowering spikes far superior to those of *C. obovatus*. Some measure 30 cm high and 28 cm wide and are deep pink in color. According to Drummer, the hybrids seem to root more freely than *C. obovatus*.

At the Arnold Arboretum we have rooted cuttings of one of Drummer's seedlings. The resultant plants exhibit a summer foliage color with a purplish cast and have exceptional vigor. Cuttings taken in May 1983 were 1.5 m tall by September and might have been taller if they had not been pinched at the top to harden stem tissue before winter set in. Drummer states that his seedlings made 1.5 to 1.8 m of growth during the 1983 season. Gardeners can look forward to the continuing development of this fine new line of garden plants.

References


The eastern hop hornbeam, *Ostrya virginiana* (Mill.) K. Koch, is a tree with an ornamental value that has largely gone unrecognized. This ubiquitous native understory tree is one of the least-studied trees in North American forests: literature searches turn up very little reliable information on its cultural requirements or ecology. In this article I will bring together the available horticultural information and point out areas where more research is needed. Lack of publicity may be the only reason that this tree has not become more popular.

*Ostrya virginiana* is the most widespread species in its genus. It is hardy to USDA zone 4 and is found from Nova Scotia to Minnesota and south to eastern Texas and Florida. The genus name, *Ostrya*, is derived from the Greek word *ostrua*, designating a tree with very hard wood (Vines 1960). Many of its common names also refer to the hardness of its wood: ironwood, leverwood, hardhack, and hornbeam. Two other common names are deerwood and Indian cedar.

The genus *Ostrya* belongs to the Betulaceae, or birch family. According to T. S. Elias (1980), it is a genus of only eight species, which are quite similar to each other. All are short deciduous trees or shrubs, with simple and alternate leaves and very short petioles. All are monoecious (bearing flowers of both sexes on the same tree). Staminate catkins are borne in groups of two or three at the tips of the previous year's twigs, and the fruits are borne in clusters of bladderlike sacs. All species exhibit rough, scaly bark.

Three species are found in the United States and Canada. Of these, two are described in horticultural literature: *Ostrya virginiana* and *O. knowltonii* Coville. Unlike the widespread *O. virginiana*, *O. knowltonii* is a rare tree, with an extremely limited range at altitudes of 1500–2100 m in canyons of southwest Texas, New Mexico, Arizona, and southern Utah. It differs from its relative in its lesser height, nearly always under 9 m. Its limbs are slender and crooked, forming a rounded crown. Its leaves are somewhat similar to those of *O. virginiana*, but they are smaller and more broadly ovate. Both its leaves and petioles tend to be somewhat more pubescent than those of *O. virginiana*, a characteristic that is typical of some desert species. The flowers and fruits are also smaller than those of the other species but similar in structure. Bark and twigs are similar.

Elias (1980) mentions the Chisos hop hornbeam (*Ostrya chisosensis*), which he
Trunk of a mature eastern hop hornbeam (*Ostrya virginiana*) at the Arnold Arboretum

describes as a shrub, rarely a tree, found in the same region as *O. knowltonii*. No other horticultural information is available on this obscure species.

Historically, the eastern hop hornbeam has been labeled a “weed tree” of no commercial value. Most management prescriptions for commercial forest land classify the hop hornbeam as a competitor to more profitable species and recommend its removal. In fact, one of the few published research papers available on hop hornbeam (*Diller and Marshall 1937*) deals exclusively with techniques of cutting the tree to reduce chances of resprouting. The authors observed that “hop hornbeam is one of the less desirable species in the farm woodlands of Ohio and Indiana. In many areas it dominates the understory so completely that the reproduction of the more valuable trees is often suppressed. . . .”

The wood of this species is light brown, tinged with red or white. The specific gravity of *Ostrya* wood is 0.83 (*Young 1933*), which ranks it among the hardest of our native woods. Its use is limited to such items as tool handles, golf clubs, mallets, fence posts, miscellaneous woodenware, and fuelwood. It is reported to take a very fine finish and probably would be a very valuable wood if the tree were larger.

The buds and catkins of the hop hornbeam are a preferred winter food of the ruffed grouse, especially in New York, Pennsylvania, and Wisconsin (*Hamilton 1974*), and the fruit is a secondary fall food. Other animals that feed on hop hornbeam are the bobwhite, ring-necked pheasant, downy woodpecker, mockingbird, purple finch, red, gray, and fox squirrels, deer, and cottontail (*DeGraaf and Whitman 1979; Hamilton 1974*).

Undoubtedly, the hop hornbeam’s greatest assets are its ornamental qualities. At one time it was recommended for use as a street tree. Restricted root space and the fact that many city trees are planted with bare roots may have been major factors in the hop hornbeam’s poor performance in the few cities where it has been tried. Because of this adverse experience, many horticultural writers unjustly removed the species from their lists of recommended trees. In cities where the tree has been located and planted properly, its performance is reported to be excellent. Nurseries in Buffalo, New York, cannot grow enough of the trees to satisfy demand (personal communication).
The hop hornbeam is small in stature, usually attaining only 10.5 m. As such it is useful for smaller properties or locations with limited overhead space. The largest hop hornbeams are found in Arkansas and Texas, where some specimens reach 18 to 21 m high and have trunk diameters of 45–60 cm. In the Northeast 10.5 m is the average maximum height, and crown spread is usually equal to two-thirds of the height. Trunk diameters are seldom greater than 15 cm and rarely reach 30 cm. The habit of the hop hornbeam is graceful, with many horizontal or drooping branches. Few trees its size can match the hop hornbeam in fineness of texture, from the narrow shaggy strips of gray bark on its trunk to its slender reddish brown twigs.

The shape of the tree is distinctly irregular, ranging from conical to oval to irregularly rounded. Understory trees are often irregularly shaped, because of the various directions of the light penetrating the forest canopy. Its status as an understory tree also means that the hop hornbeam tolerates dense shade. It is not restricted to shady spots, however, and grows well in full sun. It is in full sun that the tree develops its most desirable rounded form.

The leaves of the hop hornbeam are alternate, egg-shaped, and 7–12 cm long and 3.8–5 cm wide. The margin of the leaf is serrate. The top surface of the leaf is glossy green in summer. The lower surface is pale green and somewhat hairy, especially along the veins and midrib. Various fall colors have been observed, from a poor yellow or yellowish brown to red and even purple. Some trees retain their leaves well into the winter, though leaf retention is not a very reliable or widespread trait within the species and may perhaps be the basis for developing a cultivar in the future.

The most notable ornamental features of this tree are its fruits and flowers. The hop hornbeam gets its name, in part, from the similarity of its fruits to the true hop fruits (Humulus sp.). The compound fruit is oblong. It is made up of a cluster of bladder-like sacs, each containing a single, ovoid, faintly striated nutlet about 6 mm long. Often, the smaller sacs at the bottom of the cluster are empty. The fruit clusters become conspicuous in July, when their color is an attractive pale green in contrast to the darker green of the leaves. The fruit ripens from late August to early October, and the sacs turn tan to light brown. The sacs are covered with fine, stiff hairs that are irritating to the skin when handled.

The hop hornbeam's flowers are not dramatic or showy but are interesting nonetheless. The tree is monoecious and bears its flowers in catkins much the same way as other members of the birch family. The staminate catkins are from 2.5–5 cm long and reddish brown. They begin to expand slightly in March and then more rapidly until fully open in April, when they pollinate the pistillate catkins emerging with the leaves from beneath the bud scales.

The bark of the new shoots, twigs, branches, and trunk varies considerably and is quite attractive. The newest shoots are reddish green with minute brown lenticels. Larger twigs, and branches less than 5 cm in diameter, are smooth and purplish brown to red-brown in color. On these smooth stems the lenticels are tan to gray and lengthen horizontally, so that the young bark looks much like that of birch or cherry. Stems 6 cm and greater in diameter have the characteristic gray, narrow, striped bark that sets
hop hornbeam apart from other native trees with rough bark.

The hop hornbeam is a slow-growing tree, reaching, on average, 6 m in 20 years. Some speculate that this slow growth is responsible for the remarkable strength and toughness of the wood. The strong flexible twigs and excellent branching structure make the hop hornbeam almost impervious to damage by ice, wind, or heavy snow. Popular opinion also maintains that the species is extremely pest resistant; however, this cannot be substantiated until the tree is studied further, especially in stressful situations.

**Growing the Hop Hornbeam**

Propagating the hop hornbeam is a challenging task. The seeds exhibit a double dormancy that requires lengthy stratification in a moist medium in order to germinate. The regimen most often recommended for stratification is to place seeds in moist sand or peat for 60 days at 20°–30°C and 140 days at 5°C. An alternative regimen is 6½ months at 10°–22°C and 90 days at 5°C (Schopmeyer 1974). Despite the low percentage of germination, propagation by seed seems to be the only practical method for nursery production. Grafting hop hornbeam on rootstock of the same species, or perhaps on rootstock of another species in the birch family, may be attempted in the future at the Holden Arboretum. If the attempt proves successful, cultivars chosen for improved fall color, leaf retention, or improved growth rate may be developed. Tissue culture may also be an avenue to explore if cultivars prove to be commercially promising.

The soil and moisture requirements of the hop hornbeam are not rigid. In nature the tree is found in moist bottomland soils, near streams and rivers, and on dry, gravelly ridges, with oaks and hickories. It does not tolerate flooded or heavily compacted soils. Average garden soils will adequately support hop hornbeam, provided that drainage is good. Slightly acid soils are best but not crucial. In general, adding generous amounts of peat to average soils is the only site preparation that should be necessary when planting a hop hornbeam.

Planting sites for this tree must allow adequate space for rooting and branching. Adequate space is essential for the development of a root system that will provide necessary moisture and nutrients. Lawns less than 3 m wide, or within 5 m of a wall or building, will not provide adequate rooting space. Protection from wind is not necessary except for staking the tree during the first year or two to provide support while new roots are being formed.

Most people who know this tree agree that it is difficult to transplant successfully, especially if specimens are large. Wild trees tend to have exceptionally irregular root systems, which penetrate deeply in loose soil, so it is best to move them when they are young. Hop hornbeam should always be balled and burlapped when planted in order to improve its chances for establishment and preserve the mycorrhizal relationships the tree relies upon (Hamilton 1974).

A new approach to container growing apparently improves establishment of hop hornbeam and other species with “difficult” root systems. This approach (called the “Minnesota System”) was developed by Dr. Harold Pellett (1981) and involves the use of bottomless containers arranged in trays of standing water. This prunes the strong taproot and produces a more fibrous, compact
Eastern hop hornbeam (Ostrya virginiana) growing in a sunny location.

root system that is better able to support the newly planted tree.

The Holden Arboretum is currently promoting the use of the hop hornbeam by providing both the grower and the buyer with reliable information about this little-used tree. It is currently in the process of locating seed sources and determining the best methods of germination. Next, soils, transplanting techniques, and planting sites will be tested and evaluated to determine optimum cultural practices for growing the tree. The staff hopes to stimulate public interest in this tree by increasing awareness of its utility, ease of maintenance, and understated charm.

References


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COLLECTOR’S NOTEBOOK

New Choices for the Perennial Border

Richard E. Weaver, Jr.

Imagine a perennial border without summer phlox (*Phlox paniculata* cvs.), Michaelmas daisies (*Aster* cvs.), gayfeathers (*Liatris* spp.), Oswego tea (*Monarda* cvs.), sundrops (*Oenothera tetragona* and *O. fruticosa*) or butterfly-weed (*Asclepias tuberosa*), and you will realize how greatly the flora of the eastern United States has contributed to horticulture. But then, take a walk through a low meadow in midsummer and count the number of spectacular plants that have not found their way into our gardens. Why have so many lovely plants been largely neglected in horticulture? Some admittedly are too vigorous or invasive, or too coarse of habit, in their wild state and must await the selection of more gardenworthy forms. But more often they are simply unavailable. Nurseriesmen, and most gardeners, seem unaware of the potential our native flora still offers.

I have always been a collector of rare and unusual plants, and through my writing I have tried to introduce some of them to the gardening public. Here I would like to continue in that tradition and introduce a group of native American plants that I think would make wonderful additions to the perennial border. These are not just plants for the specialist, or plants with an esoteric beauty only appreciated by a collector. Rather, they are all easily grown and beautiful enough to be appreciated by any gardener. And they are all serviceable plants rather than novelties. All should be hardy into USDA zone 5.

Unlike annual ornamentals, which have been bred for an extended blooming season, most herbaceous perennials produce flowers for only a few weeks. Therefore, those with attractive foliage in addition to their flowers are particularly desirable for use in the perennial border. One such group is the genus *Baptisia*, of the pea family (*Leguminosae*), with 30 or more species distributed in the eastern and central United States. False indigo, the common name of the genus, refers to the fact that many of the species yield a blue dye, similar but evidently inferior to that produced from the true indigo, *Indigofera tinctoria*. One species of false indigo, the purple-flowered *B. australis*, is a standard component of the perennial border, but the others are virtually unknown to gardeners. The white-flowered *B. alba*, native to fields, roadides, and woodland margins from Virginia to Florida, is particularly fine. Like *B. australis*, *B. alba* is a bushy, clump-forming plant. The grayish, finely textured foliage reaches a height of 45 to 60 cm.

The 3-cm-long flowers in a raceme up to 45 cm long rise dramatically above the foliage, and a plant in bloom stands 90 to 120 cm tall. The flowers appear in early June, a time when few other tall plants are blooming in the perennial border. The plants are at their best in full sun but will tolerate light shade without stretching or flopping.

The wild sennas, *Senna manilandica* and *S. hebecarpa* (formerly known as *Cassia manilandica* and *C. hebecarpa*), are members of a large, primarily tropical genus, which includes plants from delicate annuals to sizable trees. Readers who have visited the tropics may be familiar with the arborescent species with their showy, bright yellow flowers followed by long, cylindrical, black pods. However, the species considered here are herbaceous perennials native to much of the eastern United States. They are similar in most respects, but *S. hebecarpa* is the more floriferous, and therefore the better ornamental. *Senna hebecarpa* is really an excellent plant, better than many commonly grown perennials. At 1 m tall it is a substantial plant, almost shrubby in aspect. The pinnate foliage is attractive throughout the summer and turns a pleasing yellow in the fall. The 2 cm, bright yellow flowers, with thick brown anthers, are borne in clusters from the upper leaf axils in August. The plants do well in full sun or light shade and once planted should be left undisturbed, because the long, thick roots make transplanting hard work.

The sunflower family

Com-
Baptisia australis has given us many of our prized herbaceous ornamentals, both annual and perennial. In what is probably the largest of all families of flowering plants, it is not surprising that many beautiful species still await discovery by gardeners. Aster is a particularly neglected genus, although most gardeners are familiar with the Michaelmas daisies, which are derived from a few of our native Aster species. Most of the species are attractive and gardenworthy in their wild state. Aster solidagineus and A. concolor are two southeastern species: one begins the aster season and the other ends it, respectively.

Aster solidagineus and several closely related species are often called white-topped asters and based on several technical characteristics are sometimes segregated as the genus Senecocarpus. Aster solidagineus is a particularly neat and attractive plant. Several to many stems with narrow, 2–5 cm long leaves arise in a clump about 38 cm tall. They are topped in July with a myriad of 1 cm flower heads. The heads are unusual among Aster species, because the ray and disc florets are the same color and the number of rays is usually less than 10. This plant does not provide a great splash of color, but it is wonderful as a delicate accent near the front of the border. It should be grown in full sun.

Aster concolor is very different from A. solidagineus. When I first saw it, while driving along a country road near my new home last September, I did not immediately recognize it as an aster. As the 60–90 cm stems are long and unbranched, with narrow, erect inflorescences, I took it to be a late-blooming gayfeather (Liatris). The color of the flower heads — pale purplish disc florets and violet rays — added to the deception (although the uppermost heads had not opened first as they do in the gayfeathers). In the garden this plant can be used much like the gayfeathers, though it is not quite so stiff and formal as those plants are. It also blooms later than the commonly cultivated Liatris species. The small silky-hairy leaves make the plant attractive even when it is not in bloom. Like many asters, it is best if grown in full sun.

This is just a small sampling of the many wonderful plants that await trial by gardeners. All of those discussed above are available from a few specialty nurseries, including Woodlanders, 1128 Colleton Avenue, Aiken, SC 29801, and my own, WE-DU Nurseries, Box 724, Route 5, Marion, NC 28752. Far North Gardens, 16785 Harrison Road, Livonia, MI 48154, supplies seed for some.

Richard E. Weaver, Jr., is the former horticultural taxonomist of the Arnold Arboretum.
More on *Forsythia* 'Meadowlark'

Dale E. Herman and Norman P. Evers

With extreme flower-bud hardiness, showy flowers, quality foliage, ease of propagation, adaptability, and vigor, *Forsythia* 'Meadowlark' promises to become a popular ornamental shrub for northern landscapes. Introduced last year by the agricultural experiment stations at North Dakota and South Dakota state universities, in collaboration with the Arnold Arboretum, the selection is hardy in the northern plains, where forsythias were previously unsuccessful. Flower buds have shown hardiness at temperatures of \(-35^\circ\text{F}\), and the plant is therefore recommended throughout zone 3 of the USDA and Arnold Arboretum hardiness maps.

The plant originated via the breeding work of Dr. Karl Sax and Haig Derman at the Arnold Arboretum. It resulted from a cross of *Forsythia ovata* (early forsythia) and *F. europaea* (Albanian forsythia). Dr. Harrison Flint, while working at the Arnold Arboretum, observed a plant from this population in full bloom after the unusually cold 1966–67 winter, while a mass planting of *F. x intermedia* 'Spectabilis' surrounding the new hybrid was nearly devoid of flowers. Flint propagated and distributed the plant, which was eventually tested by the authors in North and South Dakota. It has bloomed consistently in these states for 10 years.

'Meadowlark', which begins to bloom when only three years old, bears bright yellow flowers in profusion in early spring. In size and quality they are superior to those of both parents, and their color is a deeper yellow than that of *Forsythia ovata*.

The shrub is vigorous, drought-tolerant, and rapid growing, reaching a height of 2 to 2.75 m. Its spreading form is dense and regular.

The mature leaves are ivy green and maintain their color until late fall. A purple-bronze cast is the first indication of fall color, though the leaves often change to golden yellow under favorable fall conditions. The foliage is luxuriant and virtually pest free throughout the growing season.

This plant may partially replace several pest-ridden *Cotoneaster* and *Lonicera* (honeysuckle) species. It may also be used instead of certain large Caragana (pea shrub) and *Philadelphus* (mock orange) species with inherently leggy growth habits.

The selection is easily propagated from softwood cuttings in a 1:1 (by volume) peat-perlite medium, with 90 to 96 percent rooting common. It can also be propagated by semihardwood cuttings, by hardwood cuttings (with bottom heat), and, in limited numbers, by layers.

*Forsythia* 'Meadowlark' was officially registered in January 1984 by the Arnold Arboretum, which serves as the registration authority for the genus *Forsythia*. To date, 13 wholesale nurseries have initiated commercial propagation. Distribution to retail nurseries will begin in spring 1985.
Propagating Materials Available

Anyone interested in commercial propagation of this selection may send written requests for materials to: Dr. Dale E. Herman, Department of Horticulture and Forestry, North Dakota State University, Fargo, ND 58105. Dormant, bare root liners will be available for shipment between March 10 and May 10, 1984. Hardwood cuttings can also be supplied. Potted liners will be supplied in June and July 1984 if prior arrangements are made for pickup. Softwood cuttings can be supplied during June.

BOOKS

How to Grow Tree Seedlings in Containers in Greenhouses, by Richard W. Tinus and Stephen E. McDonald.


John H. Alexander III

An appropriate subtitle for this book might be “The Mass Production of Seedlings for Forestry.” Not a book for the home gardener, it is a manual for the professional nurseryman or prospective nurseryman.

Intending to give as much information as possible, a system of “Confidence Levels” is used to indicate assurance in some of the research. “Level A: thought to be complete and accurate. Level B: believed to be valid, but is subject to further testing. Level C: based on observation . . . offered in the view that some knowledge is better than none.”

The authors begin with the question, “should you grow your own trees?” and go on to discuss the alternatives, carefully guiding the reader through the steps necessary to determine the most appropriate size and location for a container nursery.

The first 33 pages give advice for determining size and site. A market evaluation is

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encouraged, and production costs are discussed, as are the availability and cost of fuels, water, and labor. Regarding the latter, the authors note that “... one laborer for each 120,000 trees and at least one technical supervisor for each 3,000,000 trees may be used as a rule of thumb.”

The next three chapters describe the physical plant, including topics such as greenhouse heating, cooling, and humidity controls. These are followed by chapters on containers and media, temperature and humidity, and lighting. It is the combination of temperature control and lighting that affords the great advantage of greenhouse growing over the more traditional outdoor-production methods. Lighting systems for photosynthesis and for the prevention of dormancy are described. Three standard methods of preventing dormancy are discussed. “Photoperiod can be extended by continuous lighting 4 to 8 hours after sunset or before sunrise. Night break lighting employs 2- to 5-hour interruptions during the dark period. Cyclic lighting is brief interruptions of light repeated every 5 to 30 minutes throughout the dark period. This may require lighting only 2% to 10% of the time.” Responses vary with species and within the species when growing genotypes from climatically different areas.

The longest chapter, “Mineral Nutrition and pH Control,” provides suggestions for monitoring and controlling the pH and the salt concentration in the growing medium. The authors provide a table of published works on the nutrition of forest trees, which lists research on over 40 species. They also list publications that contain color photographs of known nutrient deficiencies for 19 species. Much emphasis is given here to the preparation and modification of nutrient solutions to maintain optimum growing conditions continuously.

A chapter is devoted to formulating a growing schedule, and detailed growing schedules for 14 species are provided in an appendix.

When container-growing methods are employed for large quantities of seedlings, seeds are sown in the same container that the finished seedling will occupy. In forestry practices, the seedling tree is then planted in its permanent site outdoors. Since germination is seldom 100 percent, the nurseryman must determine how many seeds to sow in the space where he wants only one finished plant. Costs of thinning and of transplanting must be weighed; thinning is always less expensive, but the cost and availability of seed must be considered. This decision should be based on a predetermined germination percentage and the probability of germination in a proportion of the container cells. Probability tables are provided in the appendix.

Record-keeping and the efficiency gained through analysis are stressed throughout. Sample forms for maintaining records are included.

Some of the technological hardware discussed here is no longer available, having been superseded by new products and techniques.

In general, the information is well documented, readable, and frequently cross-referenced. Numerous charts, line drawings, and 45 black-and-white photographs amply illustrate it. An extensive bibliography is provided also. Although this book is primarily concerned with the growing of species important to forestry, it has much information that will be helpful to any production-oriented nurseryman.
Scaly bark of the American smoke tree (*Cotinus obovatus*). Barth Hamberg photo.
The Arnold Arboretum of Harvard University, a non-profit institution, is a center for international botanical research. The living collections are maintained as part of the Boston park system. The Arboretum is supported by income from its own endowment and by its members, the Friends of the Arnold Arboretum.