The (un)Natural and Cultural History of Korean Goldenrain Tree

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The midsummer floral and autumnal fruit displays of goldenrain tree, *Koelreuteria paniculata,* have caught the eye of Western botanists and gardeners alike since 1747, when Pierre d'Incarville, a Jesuit priest, introduced the species to Europe from northern China. By 1763, this charming tree was being grown in the Jardin du Roi in Paris, and in 1809 it made its first known appearance in the United States when Thomas Jefferson received a shipment of seeds from Madame de Tessé, a French aristocrat and fellow botany lover with whom he often traded plants. It has since become a popular garden ornamental and is much appreciated for its tolerance of urban conditions.

Goldenrain tree's Chinese distribution lies in the eastern half of temperate China, extending from Sichuan Province northeast to Liaoning Province, where it is frequently found growing in dry streambeds and valleys. About a dozen separate populations have been discovered on

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Goldenrain trees in bloom above their namesake restaurant—Mogamchoonamu—in Balsan 1-Ri, a fishing village near Pohang on the eastern coast of the Korean peninsula.

the Korean peninsula as well as in Honshu, Japan. Several theories about the origin of these populations have been proposed. The close proximity of most populations to the Yellow Sea suggests a likely route for Chinese propagules dispersed by water, man, or some combination of the two. In his 1976 monograph of the genus, Frederick Meyer of the U.S. National Arboretum states convincingly that the species' appearance outside of China was due solely to man.[1] The species was not encountered during Japanese botanist Takenoshin Nakai's thorough survey of the Korean peninsula (1915–1936).[2] However, we cannot assume they were not present at the time, as the small, isolated populations could easily have been overlooked. Contrary to the view that the species was introduced from China, the recent discovery of several inland populations has led to speculation by some that it was once naturally widespread throughout the Korean peninsula and that only a few remnant populations remain.[3]

Red dots mark the five Koelreuteria paniculata *populations the authors visited in South Korea. Locations, counterclockwise from top left: Anheung, Anmyondo, Wando, Pohang, and Woraksan.*

The cultural significance of goldenrain tree in Asia lends support to the argument for human-mediated origins. Chow noted that in China it was common around temples, palaces, and gardens and was used to mark the tombs of important officials.[4] Likewise in Japan, the use of goldenrain tree is linked to religious practices. An early researcher posited that it may have first appeared in a Buddhist monastery in Kyoto around 1220 AD, grown from seeds brought from China.[5] Ohwi, a prominent Japanese botanist of the twentieth century, also believed in the Buddhist connection, pointing out that the species had naturalized near temples along the shoreline.[6] (Buddhism arrived in Japan in the mid sixth century, most likely by way of Korea, where it can be traced back to the mid-to-late fourth century.) In Korea, the species has been preserved in local forests by villagers for use in shelterbelt plantings to protect homesteads from salt spray.[7]

Their origin is not the only aspect of the Japanese and Korean populations that has puzzled botanists. Their ability to survive the stressful conditions at the ocean's edge has also been of interest. In 1979 the Morris Arboretum's Paul Meyer collected from trees in Paengnipo (also known as Panjikol) on the west coast of South Korea. He described the population as "a dense scrubby thicket with few plants reaching more than two meters, the plants growing on sand dunes, just above the high tide level."[8] He depicted the site as "exposed to periods of sea water inundation, wind, drought and salt spray." Their unusual character also prompted collection by Arnold Arboretum botanists Richard Weaver and Stephen Spongberg in 1977.[9]

Recent studies of Korean populations, most of which now have government protection because of their biological and cultural significance, have found high genetic differences among populations but low levels of genetic diversity within them, suggesting local inbreeding and little gene flow between populations.[10] To date, however, the comprehensive phylogenetic study that would be required to establish the relationships of all the Korean populations—as well as those of China and Japan—has not been undertaken.

The first sighting of goldenrain trees was outside several marina buildings on the island of Anheung.

The Urban Horticulture Institute (UHI) at Cornell University has been studying the goldenrain tree for several years, in particular because of its tolerance of the stresses of urban landscapes. The UHI staff has assembled a diverse germplasm repository of living plants from Asia as well as from Western gardens, and has been conducting experiments in the field, greenhouse, and laboratory to better understand the species' natural variation and its physiological response to varying environments. Asia's coastal populations have been targeted to test hypotheses related to microevolution and adaptation to salt spray. However, results of *ex situ* experiments, no matter how compelling, are best viewed in light of the plant's natural habitat. Therefore, during the summer of 2004 the three authors visited five populations of goldenrain tree in South Korea, one inland and four along the coast. In addition to describing the sites and the condition of the trees, we collected tissue for future molecular analyses, measured photosynthesis to assess plant performance using a portable gas-exchange system (LiCor 6400), and, when possible, interviewed local people.

Anheung

Michael and Tom arrived in South Korea on the evening of June 14, 2004, and met Kang the following morning. During the ninety-minute drive to Seoul, we discussed woody plants of mutual interest—in particular, mogamchoon-amu (the goldenrain tree). Once at Dongguk University, we toured Kang's laboratory, readied our expedition supplies, and met his graduate

students, including Kim Tae-Young, who joined us on our trip.

The next morning, we left for the province of Chungchan Namdo, west-southwest of Seoul. In the small town of Mollipo[11] we joined Chang Kyon-Wan, chief of the western branch of the Korea Forest Research Institute (KFRI). We had intended to visit the nearby population at Paengnipo but learned that it had recently been destroyed for resort construction. (Government protection is at times more theoretical than real.) Mr. Chang recommended that we instead visit another population in the region, near the island fishing village of Anheung. None of us had heard of this population, but we eagerly hopped in our car and headed south, following Mr. Chang to our destination. Upon arrival, our guide provided us with a general lay of the land, told us where to find our target species, and then had to depart. A view with binoculars of a distant wooded hill revealed trees with pinnately compound leaves. But after rushing over we identified it as *Platycarya strobilacea,* of the walnut family, a common species in the region. This was only after discovering its strobiles, peculiar dried, five-centimeter (cm)-long, cone-like fruits. We also saw a great deal of *Pinus densiflora* (Japanese red pine) and of shrubs such as *Rhus chinensis* (Chinese sumac) and an Asian species of spicebush, *Lindera obtusiloba*—but no goldenrain trees.

A bit disgruntled, we made our way along a bumpy dirt road to the very tip of the island where we had our first sighting: two multistemmed trees growing among fishnets, traps, and a rubbish heap outside a boat rental business. They stood 4 to 5 meters (m) tall and had a dense canopy of conspicuously cupped leaves, a response to salt-spray stress. With rising spirits we followed the road a kilometer (km) up and over a final hill, past a copse of *Pinus densiflora* to the ocean's edge, where we found the actual population. We had no trouble identifying the species, for not only were the trees protected by a chainlink fence 1.5 m high, but little yellow signs labeled *"Koelreuteria paniculata"* hung from nearly every tree. Such is the nature of plant exploration in the twenty-first century.

Despite being protected, the population had not been mentioned in any previous reports, so it was important that we census the site in the few hours remaining before dusk. The trees were growing 8 to 10 m from the harbor's edge, covering about half a hectare (ha). Goldenrain tree was the dominant species, with a few small *Platycarya strobilacea, Rhus chinensis, Elaeagnus macrophylla,* harlequin glorybower *(Clerodendrum trichotomum),* and the viney *Hedera rhombea* mixed in. We counted 25 adult goldenrain trees ranging from 3 to 4 m in height but no juveniles despite evidence of fruiting the previous year. There were both single- and multistemmed trees; most were growing upright although on the stand's windward edge we found a few prostrate individuals. To describe the trees as vigorous would be an overstatement: There was widespread evidence of salt injury on the leaves, including leaf-rolling (cupping) and surface puckering. Over time, leaves exposed to salt can become chlorotic (yellowed) or even die, and we saw both. We also found misshapen branches that had shortened internodes (spaces between leaves), resulting in leaves growing abnormally close together. This, when accompanied by a windswept form, is the syndrome referred to as elfinwood, which is akin to the krumholz commonly seen in conifers at high altitudes.

At this site as elsewhere, we recorded height and stem diameter and attempted to estimate the age of the trees through increment coring. The largest diameter at breast height (dbh) was 34.5 cm and we ascertained that this stem was 72 years old. Quite a few of the multistemmed trees were noticeably larger at the base; coring one tree's base and largest stem yielded 84 and 38 annual rings, respectively. Most of the trees were similar in size and habit, suggesting an even-aged stand that may have had most of its stems cleared several decades ago. The substrate, unexpectedly, consisted mainly of cobblestones, perhaps ship bilge or dredge spoil from the nearby harbor.

The next morning we made our way to the nearby Chollipo Arboretum. This famous plant collection, situated among the coves at the ocean's edge, was founded by the late Carl Ferris Miller in the early 1970s and is at the top of the must-see list for any connoisseur of woody plants.[12] Chong Mun-Yong, the hor-

ticultural director, gave us a warm welcome and a complete tour, despite the torrential rain that marked the beginning of the monsoon season. The collections of magnolias and hollies were impressive, and the heady aroma from the blooming chinaberry *(Melia azederach)* was nearly overpowering. We also saw a number of goldenrain trees that had been collected from the now extirpated Paengnipo site; had it not been for Mr. Miller's efforts, it is doubtful that germplasm from this population would still exist. At the end of our visit, when Mr. Chong invited us to sign the institution's visitors' book, Michael and Tom laughed at how small the botanical world was—just two days before, the Arnold Arboretum's Peter Del Tredici had signed the book during his visit.

Anmyondo

Our next destination was a site near the seaside resorts of Bangpo Beach and Bangpo Harbor, on the western edge of Anmyondo, an island in the Yellow Sea to the south of the Taean Peninsula. After arriving on the afternoon of June 16 and dropping our things at the hotel, we decided to explore the area while there was still daylight. To aid in our search for the goldenrain trees, we had brought photographs taken by Paul Meyer during his 1984 visit. They showed a remote population of several hundred windswept trees at the ocean's edge, with a steep hill in the background.

Not five minutes after we set off on foot along the high-tide line from Bangpo Beach south toward Bangpo Harbor, we were surprised to stumble upon a cluster of scrubby *Koelreuteria paniculata* scattered across the base of a hill—but it was clearly not the population shown in Meyer's photos. This group consisted of about 20 small trees, all less than 2 m tall. Leaf injury from salt spray was more severe than at Anheung, but it was largely confined to the outermost leaves, and a recent second flush had produced substantial new growth. We found a motley assortment of other species growing here, including the vines *Pueraria lobata* (kudzu, the "vine that ate the South"), *Lonicera japonica* (Japanese honeysuckle), and shrubs such as *Ligustrum obtusifolium* (border privet), *Eleaegnus macrophylla,* and a shrubby member of the linden family, *Grewia biloba* var. *parviflora.* While all showed some salt damage, their growth seemed only marginally compromised. The most common symptom among these species, in addition to leaf yellowing, was succulence: many leaves become thicker when exposed to salt spray. (The *Grewia* were particularly resilient.) The substrate along the tidal marks was the same as at Anheung: large cobblestones. These stones had clearly washed ashore from the ocean, prompting us to reconsider our earlier hypothesis that the Anheung population was growing on dredge spoil or ballast rather than on naturally deposited stones.

Farther down the beach, we got our first view of Bangpo Harbor and our original target population. The site looked very different from the 1984 photos. The beach and high-tide mark, just a few meters from the population's edge in 1984, were now 75 to 100 meters away. Between the trees and the sea, parking lots, boardwalks, hotels, and restaurants had been built to accommodate the flourishing tourist and fishing industries. The goldenrain trees, covering nearly a hectare (1.47 acres), were surrounded by a formidable 1.5-m-tall wrought-iron fence painted grass green. Two large interpretive signs, in both Korean and English, described the species and the population's designation in 1962 as a monument (number 138). We laughed at our achievement in finding such an isolated population; a glowing neon sign would not have made it more obvious.

Unlike the Anheung population, this one was actively managed by local authorities. All understory vegetation had been removed and many of the trees were propped up with metal braces and cables to force upright growth. All of this had been done since 1984, when few trees were taller than 3 m; they now generally ranged between 5 and 7 m in height. Their growth and increased vigor probably resulted from the decline of salt spray over the past two decades: a breakwater now lessens the intensity of wave action, the waves themselves are farther away, and in some parts of the site, buildings now block spray completely.

We were assisted over the next few days by Kang's colleague Woo Su-Young, a professor in the Department of Environmental Horticul-

PAUL MEYER

The western edge of the Bangpo Harbor goldenrain tree population on Anmyondo as it appeared in 1984, above, and in 2004, below.

ture, University of Seoul. We had intended to measure foliar salt deposition, but recent rains had washed all the salt from the leaves. However, especially on the farthest windward canopy edges, leaf damage from earlier exposure was substantial, mostly limited to cupping/rolling and puckered (bullate) surfaces, which allowed us to assess the stress. Some leaves had been killed, but in many of these cases new growth was emerging from buds lower on the branch. We also found that looks can be deceiving, as gas-exchange measurements on mature leaves—even those with significant injury—had moderate to high photosynthetic rates.

Stem size was fairly uniform throughout, though the trees on the farthest windward edge were smaller. The stand's basal area, which is an estimate of the total cross-sectional area of all trees in the stand (here only goldenrain tree), was 14.2 m^2/ha. While we do not know what the basal area had been in previous years, we could compare dbh values. Mean dbh was nearly twice that reported by Lee *et al.* in 1997, supporting our view that the trees had grown significantly as the amount of salt spray had declined recently. Most of the trees had multiple stems that separated 20 to 30 cm above the base, and the mean basal diameter was 21.8 cm. We tried to age individuals by coring stems and bases but found internal rot in most trees beyond 25 to 30 annual rings. Despite finding copious seeds from the previous year, we found no evidence of seedling recruitment, which could be the result of poor germination and/or the removal of juveniles during clearing. This failure of seedlings to regenerate, particularly if over a prolonged period of time, constrains a population's ability to survive.

Despite this lack of sexual reproduction, we found conclusive evidence of clonal regeneration. One rainy afternoon, as we cored the base of a multistemmed tree, we removed a bit of soil from around the base and saw what appeared to be a horizontal stem leading away from it. With trowels, penknives, and fingers, we carefully excavated the sandy loam from the stem and at its end, 1.2 m away from the trunk, we found another, slightly smaller tree. Curious to explore the network further, we excavated the opposite side of the original tree and found another lateral stem, this one leading to a prostrate individual. Two other trees within 2 m of the original stem also turned out to be vegetative clones. In response to disturbance and other stressors, many temperate trees form basal sprouts.[13] To our knowledge, this is the first documented observation of stem or root suckering in *Koelreuteria paniculata.* In light of the stand's poor sexual reproduction, clonal reproduction would seem to play a critical role in its persistence and might also explain the low levels of within-population genetic diversity reported in earlier studies of coastal populations.

At the population on Anmyondo, we discovered that goldenrain tree can vegetatively reproduce from stem and root suckers.

Soil cores taken near the central stem showed a marked difference between the windward and leeward sides of the clump. The leeward side was topped by an organic layer at least 6 to 8 cm thick, whereas the windward side had a very shallow organic layer, typically of less than 2 cm. This kind of soil profile is similar to that of dune-forming

species whose networks of roots and stems capture organic matter, often their own fallen leaves. Nearer the ocean's edge of the stand, we found that soil had lower organic matter and was coarser, in many cases comprising stones similar to those we had observed at other sites.

We had wonderful meals at the Marine Motel, just a stone's throw from the goldenrain tree population. One evening, after sampling a fruity North Korean alcohol made from bilberry *(Vaccinium uliginosum),* we interviewed the proprietress, Mrs. Choi. Her family had lived at Bangpo Harbor for many generations, and she considered herself the trees' caretaker, much to the chagrin of the local authorities. She told us that the population had been there for as long as her family could recall, at least 150 years. When her grandfather was a boy, it had been much larger and was managed by the family as a windbreak to protect the homestead and garden from salt spray. She was quick to point out that it was not until the population was designated a cultural landmark in the 1960s that it shrank in size and became a monoculture. We asked about the goldenrain trees' origin, but she had no answer beyond the traditional local explanation—that the trees came from China—and had no idea of whether they had been deliberately planted or had grown from seed that floated across the sea.

A large flowering goldenrain tree growing near the fishing hamlet of Kalmun-ri, Wando. During our visit, only about half of the population had been protected by a fence; the remaining areas were used by local fisherman to store floats and nets.

Wando

The island of Wando is positioned off the south-southwest edge of the Korean peninsula and is home to an array of warm-temperate woody species such as *Camellia japonica, Actinodaphne lancifolia,* an evergreen member of the laurel family, and *Cinnamomum japonicum,* sometimes called the Japanese camphor tree. On the morning of June 21 we met Oh Chan-Jin of the Wando Arboretum, which has been coordinating goldenrain tree preservation efforts at a site near Kalmun-ri. He described the population there as the healthiest he had seen in Korea, attributing the trees' vigor to the microclimate of the site: it is on the island's northwest side, separated from the mainland by only 2.5 km and therefore protected from harsh winds off the ocean. The population came under government protection as recently as 2002 (monument number 428), and at the time of our visit only half of the area had been fenced in.

After our chat with Mr. Oh, we drove the short distance to the hamlet of Kalmun-ri, where the woods spanned several hectares along nearly a kilometer of shoreline, with most of the *Koelreuteria* in a strip running about half that distance. At the high-tide mark, a 1.5-m-high stone retaining wall had been erected along much of the site's length. Jutting from the wall was a 50-m quay, to which several boats were moored and where local fishermen unloaded their daily catches.

There was much greater species diversity here than at the previous sites, which were essentially monocultures. Bigleaf dogwoods *(Cornus macrophylla)* were in full bloom, the largest any of us had seen (several over 50 cm in dbh and

Summary of Populations Visited and Primary Sampling Data

Location and description	Latitude (N)	Longitude (E)	Number of individuals	Average dbh (cm)	Largest dbh (cm)	Oldest stem	Average height (m)
Anheung, protected population near harbor	36° 40.922'	126° 07.190'	25	12.8	34.5	86	3.5
Anmyondo, small feral population near Bangpo Beach	36° 30.423'	126° 20.0'	15 to 20	—	—	—	1.5
Anmyondo, protected population at Bangpo Harbor	36° 30.275'	126° 20.124'	ca. 375	12.4	20.6	36[a]	6
Wando, protected population at Kalmun-ri	34° 21.864′	126° 38.507'	ca. 800	18.7	46.7	53[a]	8
Pohang, westernmost edge of population near Mason-Ri	36° 0.824'	129° 28.723'	—[b]	11.5	18.4	29[a]	6
Pohang, site near Balsan 1-Ri	36° 1.614'	129° 30.157'	—[b]	19.6	32.4	45[a]	10
Pohang, easternmost edge of population near Tae Bo 1-Ri	36° 4.543'	129° 32.721'	—[b]	8.6	14.6	—	2.5
Worakson, population near Podogam hermitage	36° 54.026'	128° 5.405'	36	13.2	24.3	27[a]	8.5
Worakson, population on Joonbong Valley Ridge	36° 53.431'	128° 5.316'	20 to 25[c]	11.8	12.8	21	5
Worakson, population in Joonbong Valley	36° 53.360'	128° 5.314'	300<	20.3	35.5	—	8.5

[a] rotting of internal core limited age estimation
[b] continuous population comprising 1000s of trees
[c] mostly juveniles

10 m tall), their scaly, alligator-like bark and canopies of creamy white flowers prominent everywhere. *Acer pseudosieboldianum* (Korean maple) were also very large, one measuring 44 cm in diameter. Also present in large numbers were Korean plum yew *(Cephalotaxus koreana),* Chinese quince *(Pseudocydonia sinensis),* and Chinese hackberry *(Celtis sinensis).* The multi-stemmed Korean hornbeam *(Carpinus coreana* var. *major)* were particularly striking with their glossy, fluted, muscular bark frequently covered with moss and lichen. (This species has significant ornamental potential but is rarely seen in cultivation.) The understory in these woods was also rich, with an assortment of species including *Cinnamomum japonicum, Eleaegnus macrophylla, Grewia biloba* var. *parviflora,* and juveniles of *Cudrania tricuspidata,* a relative of the North American osage orange.

We concentrated most of our sampling efforts in a part of the fenced section that had not been cleared or otherwise recently disturbed. Mean basal area values for two parallel transects, 5 and 20 m from the beach, were 28.7 and 21.8 m^2/ha, respectively. These values, when compared to those from the Anmyondo site, illustrate the greater volume in the Wando stand. The dominance of *Koelreuteria* in the shoreline transect was easily apparent: this species' mean basal area was 15.5 m^2/ha at the edge and 1.7 m^2/ha deeper into the stand. Compared to other tree species present, goldenrain tree was the greatest in relative density (42 percent) and frequency (27 percent). Overall, the goldenrain trees here were larger than those at previous sites, some exceeding 10 m in height. Once again, we saw evidence of clonal regeneration, but we also found considerable seedling regeneration. As

at the other sites, recent rains prevented us from quantifying salt deposition on leaves, but even on robust trees we found clear evidence of salt-spray injury, mostly cupping with a minor amount of necrosis and defoliation. As might be expected, the damage was most evident where exposure was greatest, on the outer edge of the canopy and on trees nearest the ocean. Surprisingly, even the injured leaves showed moderate-to-high photosynthetic rates.

An interpretive sign near the entrance to the site described in both Korean and English the special nature of *Koelreuteria paniculata,* noting that their seeds had once been used to make rosaries. Our queries of local residents produced answers similar to those of Mrs. Choi in Anmyondo: the stand had been there for generations, likely planted as a windbreak centuries ago.

Pohang

On June 23, we left Wando driving east along the peninsula's southern coast, then north to the industrial city of Pohang, on the east coast. It was just beyond the city, at the edge of Yongil Bay and facing the open ocean, that we found the next population. We knew very little about this site and no local authorities were scheduled to meet and guide us. Instead, we relied on a set of GPS coordinates. After a few wrong turns we found ourselves on a narrow, twisting road that wound through small fishing villages along the rocky coastline. About 3 km from our target coordinates, we saw the first *Koelreuteria,* in dramatic full flower. The trees dotted the landscape for a stretch of about 10 km, between the village of Mason-Ri eastward to Tae Bo 1-Ri. In some areas, steep hillsides were blanketed with large, healthy trees in full

From left, Kim-Tae Young, Ho-Duck Kang, and Michael Dosmann conduct a vegetation survey on Wando. Kang is measuring the diameter at breast height of a Cornus macrophylla.

Goldenrain trees in full flower growing above the ocean near Mason-Ri, outside Pohang on the east coast of the Korean peninsula.

flower; in others the trees were stunted, flowerless, and almost completely defoliated. We were surprised to see a number of recent roadside plantings, not just single rows, but groves of trees planted by the dozen. We hoped that the trees had come from a local source so that the local wild population would not be threatened by genetic contamination.

A wet, gusty typhoon limited our activities over the next few days. The gas-exchange system does not work well in a downpour, and the steep and rocky slopes would have been difficult to traverse even in the driest of weather. We spent most of our time delimiting the boundaries of the population and taking samples for future genetic analysis. Trees at this site grew both on the shore—or, rather, on the cliffs above it—as well as up to a kilometer inland, in valleys protected from the marine environment. In these valleys we found many trees exceeding 12 m in height and 30 cm in dbh—by far the largest we had seen so far and all in full bloom. By contrast, near Tae Bo 1-Ri, where the ocean spray was greatest, we found fewer than 20 windswept trees, all stunted, none more than 3 m tall and 15 cm in dbh, and all lacking flowers as well as most of their leaves—good examples of elfinwood.

In Balsan 1-Ri, one of the fishing villages that lay along the road beneath the steep slopes, we stopped at a restaurant named Mogamchoon-amu, after the goldenrain tree. Beaming with pride at our interest in the trees, the owner told us the same thing we had heard elsewhere: she did not know their origin but it was common knowledge that they had been there longer than anybody could remember.

Although some trees were being lost as hillsides crumbled under the pressure of increased development, the Pohang population was large

and thriving compared to those we had previously visited and appeared to be confronting fewer threats from either nature or humans. Whereas elsewhere the trees grew in small patches at the very edge of the beach, here they spread from shoreline to inland valleys. Another difference was that many of the trees here grew atop crags and rocky outcroppings, high above the surf where they were not likely to have been planted to protect homes and gardens. In fact, as we gazed at these trees, glowing golden even in the rain and mist, we wondered if they had been planted at all.

Woraksan

With its mixture of coastal and inland environs, Pohang was a perfect transition to our final destination: Woraksan, the 1,093-m-high mountain located in central South Korea. On June 25, as we headed west through spectacularly beautiful mountains, the fishing villages soon gave way to agriculture. Woraksan ("Moon Crags Mountain") lies within a national park that encompasses temples, stone Buddha statues, and a fortress dating from at least the seventh century.

Koelreuteria grows in two areas on the mountain, one near the Buddhist hermitage of Podogam and the other in Joonbong Valley, several kilometers away. Getting to Podogam required a treacherous drive up a rugged road followed by a hike up the steep trail that leads to the mountain's peak. The hermitage, perched on one of the mountain's western ridges at about 400 m, comprised a temple, two lodges for visitors, and several small outbuildings. The site's rich history includes an account from the Unified Shilla Dynasty (668 to 918 AD) of an exiled emperor's son who took refuge in the adjacent Wang Li Cavern.

We found 36 mature trees here, mostly along the crest of the ridge. Like the trees on Yongil Bay, they grew on steep, rugged terrain, with many sprouting from cracks in the cliffs and between large rocks. They were smaller in girth than the trees at Pohang and Wando yet far more upright, likely the combined result of competition for light and absence of salt spray and wind. A precipice above the upper canopy of one of the larger trees allowed us to measure its photosynthetic rates. From this perch we got not just vertigo but also a good view of the early flowering in the trees below; we estimated that they were about a week behind those in Pohang.

The flora at this site included many species we had not seen on the coasts. We counted many Amur maples *(Acer tataricum* ssp. *ginnala),* kousa dogwoods, and a few large, flowering *Tetradium danielli* (a close relative of the Amur cork tree, *Phellodendron amurense*) and *Ailanthus altissima* (tree of heaven). The rich shrub layer contained such familiar garden taxa as Korean boxwood, spireas, *Euonymous alatus* (burning bush), and *Philadelphus* (mockorange). There were also vines such as *Parthenocissus tricuspidata* (Boston ivy), *Akebia quinata,* and the ever-present kudzu.

In the hot afternoon sun, we took a break from measurements and enjoyed a cold watermelon with the monk, Sung Kwan. He began our discussion with a synopsis of the web of all living things: plants, insects, a nearby family of black-and-white rabbits, ourselves. We hoped that our questions about goldenrain trees would elicit local legends, but instead he matter-of-factly told us that they were obviously natural elements of the mountain. When we probed further, he said that he found the trees unattractive and of so little value that he could see no reason anybody would have introduced them. He was also certain that the seeds were far too small to make Buddhist rosaries, contrary to what we had read earlier. Certainly not the responses we had anticipated.

After our chat, he led us down the path through the *Koelreuteria* grove to the Wang Li Cavern, the site of a Buddhist shrine and a spring. Directly in front of the cavern was a pool of water spanned by a rustic wooden bridge and surrounded by a dense colony of *Artemisia vulgaris* (mugwort). On the right side of the cave's mouth stood a *Taxus cuspidata* (Japanese yew) and on the left, a goldenrain tree. Suspended from a branch of the latter was a small brass bell that jingled in the breeze, adding to the atmosphere created by the spectacular valley view and the strong smell of camphor from the mugwort. The human footprint on this mountain stretches at least back to the Goryeo

Dynasty (57 BC to 668 AD), when the nearby Dongmun fortress was built, and contrary to the monk's assertion we were quite sure that at some time in that long history *Koelreuteria* was introduced at Woraksan.

We spent the next day, our last on the mountain, investigating a population of goldenrain trees in the nearby Joonbong Valley. In an earlier report[14] Son numbered this population in the hundreds, but after an arduous hike we found only about 25 individuals in an isolated patch on a ridge at 395 m. Most were juveniles; only a few of the larger trees had flowers. Certain that this could not be the population mentioned by Son, we spent several more hours exploring the area but failed to find more *Koelreuteria,* and we headed back down the mountain at dusk.

Before leaving for Seoul the next morning (June 28), we returned to the valley for a quick examination of a streambed to the south of the ridge where we had found the small population the day before. Almost immediately, we found hundreds of *Koelreuteria* lining the very edges of the rocky waterway. Many were exceptionally large, a few exceeding 15 m in height and 35 cm in dbh. Nearly all were multistemmed, and again we saw evidence of basal sprouting following disturbance, in this case subsidence of the unstable banks. In fact, we saw very large trees, some still alive, that had been uprooted and washed downstream. Water, wind, and gravity are known dispersal agents for the marble-like goldenrain tree seeds; here we saw that entire trees, not just seeds, could be dispersed by flowing water. Although we

Tom Whitlow uses the LiCor 6400 to measure photosynthesis on a tree growing near the Buddhist hermitage at Podogam on Woraksan. The real-time photosynthetic rate (expressed as the rate of CO_2) is determined after inserting a leaf in the unit's cuvette, seen attached to a tripod on the righthand side of the image.

never determined the entire size of this population, we were confident that it continued for a considerable distance toward the crest of Woraksan.

On June 30, we visited the Korea National Arboretum, about an hour's drive north of Seoul. After a wonderful tour of the grounds, we met with several KFRI research scientists who were familiar with *Koelreuteria paniculata*. We were surprised to learn from Kim Sung-Sik that two bird species, the brown-eared bulbul *(Hypsipetes amaurotis)* and the rufus turtledove *(Streptopelia orientalis)*, have occasionally been observed foraging in the Arboretum's goldenrain trees. Rather than eat the seeds, the birds usually drop them short distances away. None of the literature on goldenrain tree mentions seed dispersal by birds, but this behavior could explain the presence of populations on the high cliffs of Pohang and on the isolated ridge at Woraksan, making birds yet another dispersal vector in addition to wind, water, gravity, and people.

A goldenrain tree stood at the mouth of the Wang Li Cavern, near Podogam, the Buddhist hermitage on Woraksan.

Our first goal when we embarked on this tour had been to study the Korean goldenrain trees in their natural (or unnatural) environs. We were expecting to find uncultivated populations regenerating on their own and blending with other natural elements of the landscape. At two locations, Pohang and Woraksan, this is exactly what we found. We were not expecting the heavy human influences we found at Anheung, Anmyondo, and Wando, however, where the populations resembled plantations not long out of management. Nevertheless, we concluded that all the sites we visited reflected the essential nature of *Koelreuteria* in Korea: all are components of cultural landscapes that are intertwined with local traditions ranging from Buddhism to coastal homesteading. And we believe that each population, whatever its origin, now represents a unique cultural landrace that should be preserved, just as we preserve landraces of crop plants.

The second reason for our trip was to learn how goldenrain tree responds to a coastal environment where it must cope with the stresses of salt-spray and other disturbances. The intense monsoon rains we encountered on many days actually provided valuable insights in this regard. As tender leaves emerge in spring, they become stressed from the constant salt spray. This progresses from chlorosis and cupping to death in severe cases, particularly in leaves at the windward edges of the canopy. When these early leaves are damaged, as we observed during our visit, a second set of buds below them is released from dormancy and a new flush occurs with the onset of the monsoon season, producing leaves that are likely to last through the rest of the summer. Although salt is no doubt deposited on the new leaves, the frequent rains rinse much of it away, a process likely facilitated by the curling of the leaves. And, we learned that despite visible signs of salt injury, leaves could still photosynthesize at moderate to high rates. Stem- and root-suckering, a strategy for mitigating the effects of stress and disturbance, help the trees survive

in these sites and may explain the low levels of within-population genetic variation reported in earlier studies. The combination of all these factors may be the source of the species' survivability at these coastal sites.

Regardless of how *Koelreuteria paniculata* arrived on the Korean peninsula, the trees are entrenched in local custom and deserve to be preserved for generations to come, for their cultural as well as scientific significance. The South Korean government's protection of most of these populations is commendable, but the lack of appropriate management threatens the trees' long-term survival. For example, clearing the understory at Anmyondo has limited potential regeneration, both seedling and clonal, and the roadside trees planted near Pohang could contaminate the local gene pool if they are not derived from local source. We strongly recommend a centralized management plan that includes long-term demographic monitoring and evaluation, less intrusive maintenance measures, and preservation of germplasm in *ex situ* repositories.

Endnotes

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[9] S. A. Spongberg. 1978. Korean adventure. *Arnoldia* 38: 132–152. Specimens from these two separate collections can be admired at both arboreta. Meyer's collection (KT 74) yielded Morris Arboretum accessions 81-333 ADEFH, and Spongberg and Weaver's collection (SW 356) produced accessions 1605-77ABC for the Arnold Arboretum.

[10] S. W. Lee et al. 1997. Characteristics of leaf morphology, vegetation and genetic variation in the endemic populations of a rare tree species, *Koelreuteria paniculata* Laxm. *Journal of the Korean Forest Society* 86: 167–176; Son et al., 2000; K. B. Yim, et al. 1994. RAPD variation in three distantly isolated populations of *Koelreuteria paniculata* growing in Korea. *Research Reports of the Forest Genetic Research Institute of Korea* 30: 93–98.

[11] The names for the local sites (Mollipo, Chollipo, and Paengnipo) reflect the relative sizes of their bays: the suffix "-po" means bay, while the prefix "moll-" means large (c. 10,000), "choll-" means medium (1,000) and "paengni-" means small (100).

[12] Spongberg, 1978, describes both the young garden and their host of 25 years ago.

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[14] Son, 2000.

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