Degradation of coastal forests and associated wetland habitats by excessive flooding and saltwater intrusion is a global problem, and may become even more so if predicted climate changes and consequent rises in sea level occur. In the United States, there’s been great concern about the degradation of the entire Mississippi River Delta biotic system, much of which can be traced to man-made changes in the nature and flow of the Mississippi river. One example of this degradation is the loss of coastal forests south of New Orleans, which has left this city more vulnerable than ever to the impact of hurricanes. (Allen 1992; Earles 1975; Krauss et al. 1999)

These circumstances make it increasingly important to identify, select, and even improve tree species that have some innate tolerances to flooding and salinity. Such trees will be valuable for restoring degraded coastal areas as well as for urban landscapes and other greening projects. For this reason, we are particularly interested in *Taxodium distichum*.

**TAXODIUM TAXA**

Of all native swamp forest tree species in the southern United States, *Taxodium distichum* (baldcypress) has long been recognized as being among the most tolerant to flooding and salinity. This long-lived and generally pest-free

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**Can *Taxodium* Be Improved?**

David Creech, Lijing Zhou, Yin Yunlong, and Teobaldo Eguiluz-Piedra
deciduous conifer is a popular landscape tree in many parts of the world. Once established, *Taxodium* is tolerant of flooding, salt, alkalinity, and strong winds.

The precise nomenclature for *Taxodium* remains a matter of some debate. Once considered three species—*T. distichum* (baldcypress), *T. ascendens* (pondcypress), and *T. mucronatum* (Montezuma cypress)—we believe there’s enough consensus in recent literature to list *Taxodium distichum* as a single species with three botanical varieties:

- *Taxodium distichum* (L.) Rich. var. *distichum* (baldcypress)
- *Taxodium distichum* var. *imbricarium* (Nutt.) Croom (pondcypress)
- *Taxodium distichum* var. *mexicanum* (Carriere Gordon) (Montezuma cypress)

(Arnold and Denny 2007)

While baldcypress and pondcypress natural ranges overlap in many areas across the South, the commingling of baldcypress and Montezuma cypress natural ranges is less apparent. Hardin (1971) was the first to speculate on the nature of intermediates where baldcypress and pondcypress ranges overlap. The same is perhaps true for baldcypress communities in central and southwestern Texas. They are often Montezuma cypress-like, leading many to believe this is the result of natural introgression present between baldcypress and Montezuma cypress in this transitional zone.

**Baldcypress** is native to much of the southeastern United States, from Delaware to Texas and inland up the Mississippi River to southern Indiana. It occurs mainly along rivers with alluvial flood deposits. Baldcypress is a durable conifer particularly well adapted to wetland habitats. It is easy to grow from seed and is relatively free of pests and diseases. The tree is modestly to highly resistant to *cercosporidium* needle blight and tolerates compacted soils and low-oxygen or swampy soil conditions. It stands strong in the face of hurricanes, is amazingly long lived (1,000+ years) and, with time, can become quite large (70+ feet [21+ meters] tall). Baldcypress produces knees (pneumatophores), which are considered a negative in most landscaping situations since they can
interfere with routine maintenance such as lawn mowing. While their exact function is unknown, knees may contribute substantially to wind throw resistance (Conner et al. 2002).

Baldcypress in the western part of its range (central and western Texas) is generally more salt and alkalinity tolerant, and is less prone to produce knees than baldcypress from more eastern sources. East Texas genotypes of *Taxodium* planted in San Antonio, Texas, where soils are highly alkaline, often turn chlorotic and perform poorly. As with pond cypress and baldcypress, botanists and horticulturists speculate that baldcypress in central to western Texas are perhaps commingled with Montezuma cypress and represent transitional genetics (Lickey and Walker 2002).

**Pondcypress** occurs in the southern portion of the range of baldcypress and only on the southeastern coastal plain from North Carolina into Louisiana. While southeast Texas is not normally included as part of the pondcypress natural range, an approximately 1,200-year-old pondcypress at Shangri La Gardens, Orange, Texas, appears to broaden the range. Pondcypress occurs in blackwater rivers, ponds, bayous, and swamps, usually without alluvial flood deposits. Pondcypress is relatively easy to distinguish by its feathery foliage, which is ascendant, rather than more splayed and flat as in baldcypress, but this may not always be consistent. Landscapers often use pondcypress as a specimen, particularly when moist soil conditions exist and a smaller stature (40+ feet [12+ meters]) is desired.

**Montezuma cypress** should probably be named Moctezuma cypress because by all accounts it has the name of the fifth Aztec King, Moctezuma (1466–1520), whose reign included the first contact between the Mesoamerican civilization and Europeans. It is popular in Mexico among pre-Hispanic cultures and is widely planted in public parks and gardens in most major cities in Mexico. A Montezuma cypress near Oaxaca, Mexico, the famous “Árbol del Tule,” features a trunk over 56 feet (17 meters) in diameter and is estimated to be over 2,500 years old.
Montezuma cypress is native to Mexico (in 27 of the 32 states), some areas of Guatemala, the tip of South Texas, and, perhaps, a few populations in New Mexico. It typically grows next to water sources such as creeks, rivers, lakes, and ponds and performs better in deep loamy soils than in volcanic soils where firs, pines, and oaks are found. While it will grow in a hot tropical climate, it does not perform best there.

Montezuma cypress differs from baldcypress and pondcypress in several ways: it is substantially evergreen, produces smaller seeds, never produces
distinct knees, is generally more tolerant of salt and alkaline soils, and is less tolerant of extended flooding. At Stephen F. Austin State University Gardens in Nacogdoches, Texas, Montezuma cypress forces new growth early in the spring and continues to grow late into the fall. Observations of Montezuma cypress in USDA plant hardiness zone 8 (average annual minimum temperature 10 to 20°F [-12 to -7°C]) and lower suggest that there may be hardiness and winter damage issues, particularly with trees derived from lowland, subtropical Mexican genotypes. This may be a seed source provenance problem, and there is good reason to believe that Montezuma cypress can be grown much further north if the proper genotypes are selected as seed sources.

Montezuma cypress is not usually considered a superior landscape tree in the southern United States since it often fails to form a strong central leader and is generally more susceptible to *Cercosporidium* needle blight than baldcypress, especially when grown in humid areas. However, there are exceptions, and further breeding and selection may bring better choices. At Stephen F. Austin State University Gardens there are several Montezuma cypress specimens worth noting, including one that survived the December 23, 1989 freeze [0°F [-17.8°C]] with no damage. Over the years, Montezuma cypress has withstood droughts of considerable magnitude at Stephen F. Austin State University Gardens. In fact, we note that Montezuma cypress can shed almost all its foliage in a summer drought, yet it will push new growth when rain or irrigation finally returns. Montezuma cypress kept in a high state of vigor often keeps foliage through mid-winter.

In Mexico, Montezuma cypress is much appreciated, but little genetic improvement has been undertaken. Coauthor Teobaldo Eguiluz-Piedra is supervising a large planting of genotypes near Texcoco, Mexico, that includes ten provenances. While just in the first year, there are already apparent differences in foliage color, tree form, growth rate, and branching characteristics. In Mexico, Montezuma cypress is considered quite variable from one provenance to another and nursery conditions can greatly impact growth rate and form. The Viveros Genfor nursery in Texcoco has grown Montezuma cypress for the last twenty years and reports that it requires no more water than ash, oaks, or other conifers, contrary to what might be expected from Montezuma cypress’s natural preference for a riparian habitat. Most of the nursery’s propagation is by seed collected from mature trees that are more than 500 years old. Viveros Genfor is also cloning the oldest Montezuma cypress trees nearby using juvenile tissue from rooted cuttings with a modest success rate.

**TAXODIUM CULTIVARS**

While most *Taxodium* plants sold in the United States are seedlings, there are a number of cultivars available, primarily of baldcypress. Mostly available as grafted trees through specialty nurseries, baldcypress cultivars vary in form, ultimate size, and foliage color. For over twenty years, Stephen F. Austin State University Gardens has acquired a wide array of cultivars from specialty nurseries, arboretum and botanical garden collections, and private conifer enthusiasts. Baldcypress cultivars at the Gardens
include ‘Sofine’ (Autumn Gold™), ‘Pendens’, ‘Mickelson’ (Shawnee Brave™), ‘Fastigiata’, ‘Contorta’, ‘Secrest’, ‘Hurley Park’, ‘Peve Minaret’, ‘Peve Yellow’, ‘Jim’s Little Guy’, ‘Cody’s Feathers’ (synonym ‘Wooster Broom’), ‘Cave Hill’, ‘Cascade Falls’, and ‘Falling Water’. Only two pondcypress cultivars are listed—‘prairie Sentinel’ and ‘J.B.—and two cultivars of Montezuma cypress, the mounding weeper ‘McClaren Falls’ and modestly weeping ‘Sentido’, can also be seen in the collection. In addition to cultivars, Stephen F. Austin State University gardens has numerous specimens of baldcypress, pondcypress, and Montezuma cypress from a wide range of documented provenances.

**TAXODIUM HYBRIDS**

Controlled *Taxodium* hybridization (crosses between botanical varieties of *Taxodium distichum*) can combine the best characteristics of superior parents and allow for selection of superior clones from the progeny. Much hybridization work has occurred at the Nanjing Botanical Garden, where selection criteria for controlled cross and open pollinated seed crops include growth rate, salinity and alkalinity tolerance, flooding tolerance, *Cercosporidium* needle blight resistance, form, and ease of cutting propagation. In several studies in China, *Taxodium* hybrids often demonstrated improvements in growth rate, salt tolerance, form, and vigor.

One *Taxodium* hybrid was given the cultivar name ‘Nanjing Beauty’ and was cooperatively introduced in 2004 by Nanjing Botanical Garden and Stephen F. Austin State University Gardens. A baldcypress × Montezuma cypress cross, this clone was originally selected in 1988 from the breeding work of Professor Chen Yong Hui at the Nanjing Botanical Garden. Chen and others report that the selection’s attributes include 159% faster growth than baldcypress, longer foliage retention in fall and early winter, and no knees. It also tolerates alkaline soils and fairly high salt concentrations. Cuttings root at good percentages and the clone is commercially available in China. ‘Nanjing Beauty’ is currently under evaluation in over 30 locations in the southern United States and is offered by several nurseries across the South.

Additional crosses made at the Nanjing Botanical Garden in 1992 used pollen from a superior selection of Montezuma cypress applied
Planted at the Stephen F. Austin State University Gardens in March 2010 as small one-gallon-container plants, these specimens of “merit” clone T406 from China had a very fast growth rate. This photograph is from July 2011.

As asexual propagation of *Taxodium* For superior *Taxodium* clones to make a substantial impact on nursery numbers, it is important to propagate asexually. While grafting is common (especially for ornamental cultivars such as those with dwarf or weeping forms), it is expen-
Taxodium in China

*TAXODIUM* varieties and hybrids play a very important role in the southeastern China coastal vegetation plan, particularly in the floodplains of the delta and associated bottomlands and estuaries of the Yangtze River. The planting of coastal windbreak forests in this area was initiated in 2005. There are many reforestation projects under way on the mainland side of dikes that run along the sea, both north and south of the mouth of the Yangtze. These projects have received massive provincial and federal financial support and millions of trees will be planted by midcentury.

*Taxodium* hybrids have also found a place in many of the large parks being constructed in the major cities of southeastern China. As grand allées or individual specimens, many Chinese foresters feel that in this region of China baldcypress is indeed a special tree. It has become more and more popular in the nursery industry, competing primarily with *Metasequoia*, *Glyptostrobus*, and others.

Cutting propagation of *Taxodium* is generally reported as difficult, but rooting success is influenced by genotype, the physiological age of the clone, rooting hormones, substrate, and the vigor of the cutting wood. (Pezeshki and DeLaune 1994; St. Hilaire 2003; Zhou 2008).

Young trees generally root with greater ease than older trees. Coauthor Yin Yunlong reports that the original plant of ‘Nanjing Beauty’, selected in 1988, has over time become more difficult to root, a condition attributed to chronological and physiological age factors.

To counter lower rooting percentages, a strict protocol for achieving cutting propagation success has been developed. Small well-rooted liners are field planted at close spacing and grown for one year, with trees often reaching 3.3 to 6.6 feet (1 to 2 meters) in the first growing season. Then, in that first winter, they are cut back to 1 foot (0.3 meters) tall. These pollarded trees produce vigorous upright shoots in the spring. Cuttings are collected in early summer and one upright shoot is left on the stock tree to grow for the rest of the season into a straight tree, 6.6 feet (2 meters) tall, ready for sale in the winter. Yin Yunlong notes that collecting cuttings from upright shoots produces upright growing plants of better form than trees produced from cuttings taken from side branches, a technique to avoid the problem of plagiotropic growth.

Early summer cuttings are rooted under part shade to sun, using intermittent mist and a well drained mix in deep rooting beds. While rooting hormones are utilized, cutting wood quality and maintaining good turgor are recognized as critical factors for high rooting percentages (80+%). Four cutting trials in 2006 at Stephen F. Austin State University Gardens indicated that a high concentration of K-IBA (5,000 to 10,000 ppm) improved rooting as did slightly wounding the basal portion of the stem. Other studies indicate better rooting with hormones, very well drained substrates like perlite, and no wounding (Zhou 2007, King et al. 2011).
IMPROVING *Taxodium*

Several *Taxodium* germplasm collections exist in the southern United States but they remain relatively unexploited. In addition to the *Taxodium* collection at Stephen F. Austin State University Gardens, Dr. Donald L. Rockwood, University of Florida, Gainesville, Florida, manages a large planting of varied genotypes, many of which serve as seed sources for superior seedlings, with plantings that target tolerance of fly ash, salinity, or polluted soils. Dr. Ken W. Krauss, at the United States Geological Survey, National Wetlands Research Center, Lafayette, Louisiana, is collecting seed from survivor trees in the Mississippi Delta that have been exposed to increasing inundation and salt surges [Krauss et al. 2000; Conner and Inabinette 2005]. By cruising the massive “ghost cypress forests” (large stands of dead or declining baldcypress) of the southern delta, individual survivor trees can be found that perhaps have good resistance to subsidence and high salinity. Their progeny may offer promise for reforestation projects in marginal sites, and the opportunity for selecting superior clones is immense. Finally, Dr. Mike Arnold, Texas A & M University, College Station, Texas, has planted a large collection of baldcypress genotypes from across the South; the collection includes central and western Texas provenances, as well as a collection of Montezuma cypress from Mexico and southern Texas [McDonald et al. 2008]

At the government nursery near Jinjiang (Jiangsu, China), I viewed over a million *Taxodium* cuttings in the one-acre field of propagation beds during a visit in September 2011. The nursery manager, Mr. Zho, employed a half-dozen ladies who used high-pressure hoses to hand mist the cuttings. Every day, for 8 to 12 weeks, each worker managed her own long run of propagation beds, dragging her hose and wand and waving a stream of mist over the crop. After each run, the ladies would rest and visit with each other, waiting until the beads of water on the cuttings had evaporated, the signal that it was time to repeat the process. When I asked why he used this strategy, Mr. Zho reflected that he had previously used automated boom misters on a timer, but he had found that the ladies knew better when the cuttings needed water—they had a feel for the crop—and rooting percentages were now very high.

—David Creech
**Taxodium** has many positive environmental attributes as a wetland species and as a landscape plant. It is fortunate that there is such great diversity available in the baldcypress, pondcypress, and Montezuma cypress gene pool, since with great diversity comes great opportunity for selection. No doubt superior **Taxodium** clones can be found in the progeny from controlled cross and open pollinated seeds. Improvements in salt and alkalinity tolerance, growth rate, resistance to *Cercosporidium* needle blight, drought resistance, and form could be expected from a breeding program. In the United States and Mexico, where **Taxodium** is used primarily as an ornamental, the market for improved **Taxodium** cultivars is relatively small in comparison to China, where **Taxodium** has a huge market built on hundreds of “greening” companies vying for government contracts. Millions of trees are needed for a wide array of development projects: large gardens and parks, highways, railroad lines, canal edges, and the coastal windbreak forest project. We have much to gain by connecting the native **Taxodium** germplasm resources in the United States and Mexico with the many **Taxodium** improvement projects under way in China.

**Literature**


Introduction of merit *Taxodium* clones of the Nanjing Botanical Garden http://sfagardens.sfasu.edu/UserFiles/File/PLANTS/Taxodium%20breeding%20brochure%20feb%202010.pdf

For a more extensive literature review, access the MS thesis and PhD dissertation of coauthor Lijing Zhou under “Arboretum” then “Links” on the Stephen F. Austin State University Gardens website http://sfagardens.sfasu.edu

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