

OAK TRANSPLANTATION: DOES THIS REALLY SAVE THE TREES?

Rosi Dagit,

Certified Arborist and Senior Conservation Biologist,
Resource Conservation District of the Santa Monica Mountains,
122 N. Topanga Canyon Blvd., Topanga, CA, USA 90290.

*Portions of this article originally appeared in *Western Arborist* Volume 28 (2):12-13.

Introduction

Since the development boom of the 1980's began, many mature oaks in Los Angeles County, California were moved from one place to another. Developers loved the idea of being able to "save" the trees and incorporate them into their new and improved landscapes. The tree moving companies became expert at the extremely difficult technique of actually moving a boxed tree weighing many tons. New homeowners in the developments loved the idea of having a mature tree in their yard, and paid as much as 30% more for the privilege. The decision makers felt that they had required adequate mitigation for the loss of native oak woodland. No one looked to see what the trees were saying.

Unfortunately, there have been few scientific studies looking at the effects of moving these mature trees. Roberts and Smith (1980) did a one-year study of the impacts of root loss on water potential and stomatal conductances of oaks. Scott and Pratini (1992) followed the health and vigor of 593 transplanted coast live oaks in Orange County, California for more than 4 years. Their data indicates that there was less than 20% survival of trees larger than 6 inches (15 cm) in diameter.

Methods

Starting in 1992, I led a study monitoring transplanted oak trees in the City of Calabasas, California (Dagit and Downer 1999, 2001). A total of 87 mature Coast Live Oaks were moved at four locations in the City. We began our observations as the trees were boxed and have followed them quarterly ever since.

First came the boxing. For 25 trees, the canopy was reduced by over 70% before root pruning. The canopy of the other 62 trees was left intact, with only dead branches or those damaged during boxing removed. Then a backhoe dug a 6-foot (1.8 m) deep trench around the tree from 4-15 feet (1.2 - 4.6 m) away from the trunk. Over 90% of the root system was lost. The sides of the box were built and the trees sat for 3-6 months. Then the bottom was dug out and the floor of the box was installed. Huge cranes carried the trees to either their new home or a storage site. No soil samples were taken to determine compatibility with the original site. Only in some cases were the trees replanted in their original orientation. Water trucks came weekly or more, except on one site where irrigation was installed.

Our monitoring was both qualitative and quantitative. Each tree was given a vigor rating using the International Society of Arboriculture standard condition evaluation for landscape trees which is based on canopy, foliage, trunk, and root condition. Trees were categorized as healthy (5), stable/improving (4), stable (3), declining (2), and dead (1). We also measured the shoot length, and the number of shoots and leaves per shoot. Soil probes were used to determine root distribution

and density. Leaf nutrient and soil food-web composition were also evaluated.

In addition, we used a technique called stem xylem potential to measure the water stress inside the conducting vessels. A twig is inserted into a pressure chamber at mid-day when the tree is in full sun, and then another sample is taken in the middle of the night. The amount of pressure it takes to force water out of the stem is the same needed by the tree to draw it in. By comparing the amount of pressure it takes to force water out of the stem at night when the tree is in equilibrium with its environment, with the pressure when the tree is in full sun, it is possible to see how well the tree is able to access water in the soil, and the extent of transpirational recovery.

Results and Discussion

The control trees (native trees left in their original locations) all remained healthy during the 10-year study, and measurements of their stem potential indicated that even when severely drought-stressed, they had enough reserves to rebuild lost conducting tissue. Even during the hottest months, the canopies remained vibrant and the trunks showed active radial growth.

The transplanted trees were not as stable. Extremely high stem xylem pressures were recorded, indicating a continuing decline of conductance. Because the transplants had lost so much canopy and/or root mass, they have not had sufficient energy reserves to recover. Since replacing roots takes priority over replacing conducting vessels, the trees are in a state of cumulative decline.

A quick note about oak tree biology. There is a complicated feedback loop between the new shoots and the roots that regulate their growth. Auxins (a growth regulator found in plants) in the terminal buds stimulate root growth in the late summer and fall. The roots grow and produce hormones that stimulate new shoot growth in the spring. When the trees lost both large amounts of canopy and roots, this system was completely disrupted. Regeneration of root mass is related to tree diameter. It seems that it takes between 10 and 12 months per inch diameter to regenerate lost roots under ideal conditions (Watson, 1985). The transplanted trees varied in size, but using this guideline, it would take more than 10 years for the smallest trees to redevelop lost roots. Due to the loss of canopy, the trees have reduced ability to regenerate either roots or energy reserves.

Those trees whose canopies were left intact initially fared considerably better. They maintained a well-formed canopy that appeared to shrink back to a size manageable for the tree given the extent of root loss. These trees also were faster at regenerating fine root mass, and leaf analysis indicated that the non-pruned transplanted trees maintained higher levels of calcium in their leaves than did the pruned transplants. Calcium is a critical element in tree metabolism, and the declining and extremely low levels found in the pruned trees illustrated yet another large disruption of physiologic function that the trees had to face.

The canopy configuration was also notably different. The non-pruned trees maintained a normal pattern of twig growth, similar, although smaller, than that of the control trees. After a few years though, most of them began to have more epicormic growth from the main branches and trunk, with less terminal twig growth. This was the pattern seen from the start with the heavily pruned trees. The trees were so stressed that the dormant cells in the trunk and scaffold branches were activated in a desperate attempt to gain more leaves. The pruned trees slowly replaced their canopy starting in the interior and moving out. After 10 years, many of

the original large branches are dead and have been replaced with central, poorly attached regrowth.

Another interesting fact is that the interior leaves of the oaks continue to photosynthesize during the hot summer months when the outer shell of leaves shuts down to reduce transpirational moisture loss. This little extra bit of energy generated in the moist interior of the canopy allows the tree to exceed its baseline metabolic needs for the year and store energy. When the canopy is pruned so heavily that the interior is exposed with few leaves left, the tree can just barely survive. It takes several years for the tree to recover from a severe pruning when its roots are in good condition, much longer when the roots are damaged. This is why it is important to only prune oaks when absolutely necessary. The poor transplanted trees are using up their energy reserves day by day, just to stay alive.

By April 2002, only 5 of the 87 transplanted trees were established or self-sufficient. In the ten years of the study, 17 trees have died, 44 more are declining and only 21 are stable. At this rate, the long-term survival rate for the trees is at most 40%, with 10-20% being more realistic. Considering that it cost almost \$1 million to move these 87 trees and approximately \$60,000 per year to maintain and monitor them, transplanting oak trees does not appear to be a cost-effective mitigation. Think of how many new oaks could have been planted for that sum. Think of how much existing oak woodland could have been purchased for public open space.

It appears that even the highest level of care is not sufficient to overcome the trauma of transplantation for most oaks. None of these trees suffered from lack of care from experienced arborists. Being such strong individuals, there are always exceptions to the rule. Perhaps the most famous oak transplantation project took place between 1928-1947 at Hearst Castle. Architect Julia Morgan and gardener Norman Rotanzi supervised the relocation of 6 large oaks (*Q. agrifolia*), several of which were merely turned in place or moved a short distance from their original location into fairly undisturbed soils. Creation of the trenches around each tree and pouring the concrete containers took approximately 6 months and cost roughly \$18,000 per tree. This transplanting effort has been cited as a "success story" as the trees survived for many years (Pavlick et al 1991).

These trees received extensive and increasing maintenance over the years, including some canopy reduction at the time of boxing and subsequently as the trees began to decline. Water and mulch were carefully applied over the years, although flower beds were also established within the dripline. According to Hearst landscape historian Robert Pavlik (pers. communication), the trees continued to slowly decline over the years and as of February 1994, only 1 remained alive. This tree has lost major scaffold branches, with those remaining are held up by props in a bed of azaleas.

If the goal of mitigation is to replace lost resources, then transplanting oak trees should be recognized for what it is. There may be some occasions when it is deemed necessary to move an individual tree, but we should acknowledge that the transplanted tree is no longer a self-reliant native, but rather a high-care exotic. The true cost of taking care of the tree as it slowly declines over the years should be made clear from the start. Additional mitigations to replace the lost natural resource should also be required.

In natural settings, oak trees are considered to be a "keystone" species upon which thousands of other species depend for some or all of their life cycle needs. Coast live oaks are known to be critical habitat and food sources for over 5,000

species of insects, and hundreds of birds and mammals. Large mature trees are ecosystems unto themselves, providing essential ecological and aesthetic benefits, not to mention more economically accountable benefits in stormwater-runoff reduction, temperature modification, pollution mitigation and groundwater recharge. Removing big oak trees creates enormous holes in the local and regional ecosystems, leaving gaps that take decades to heal.

Placing these transplanted oaks into manufactured landscapes does not generate the same benefits. In addition to the high costs of maintenance, the trees are often isolated and surrounded by exotic landscaping that provides little, if any, chance for the ecosystem associated with the tree to become re-established. Many birds normally associated with oak woodlands fail to nest in isolated trees located in suburban yards. The transplanted trees stand as lonely sentinels of misplaced efforts, devoid of the vitality found in healthy trees integrated into their environment.

Conclusion

Oaks, like all other trees, evolved to stay in one place for their whole lifetime. This is a difficult concept for humans, for whom movement is an essential part of our worldview.

While we have developed the technology to move the trees, that doesn't mean that we are "saving" them. To save an oak, we need to leave it in place and work around it using the most sophisticated protection skills possible to reduce the impacts of construction. Imagine how beautiful it could be to have a development work with its oaks and land forms, rather than reorganize them! Truly a goal worth striving for! Only then will we be truly **saving** the oaks.

References:

- Dagit, Rosi, Downer, A. James. 1999. *Transplanted Coast Live Oaks (Quercus agrifolia) in Southern California*. Journal of the International Oak Society 9:145-150.
- Dagit, R. and Downer, A. J. 2002. *To Prune or not to Prune: Responses of Coast Live Oaks (Quercus agrifolia) to canopy retention during transplanting*. IN: Proceedings of the Fifth Oak Symposium: Oaks in California's Changing Landscape. Richard B. Standiford, Douglas McCreary and Kathryn L. Purcell, Technical Coordinators. Held Oct. 22-25, 2001 in San Diego, CA. USDA Forest Service Pacific Southwest Research Station Gen. Tech Rep. PSW-GTR 184. 369-380.
- Pavlik, B. et al. 1991. *Oaks of California*. Cachuma Press, Los Olivos, CA. 184 pp.
- Roberts, Stephen W., Smith, Robin I., 1980. *Aspects of water relations in Coast Live Oaks and Valley Oaks subjected to root damage from land development operations*. In: Plumb, T.R. Technical Coordinator. Proceedings of the symposium on the ecology, management, and utilization of California oaks; June 26-28, 1979; Claremont, CA. Gen. Tech. Rep. PSW-GTR-44. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 171-175.
- Scott, Thomas, and Pratini, Nannette. 1992. *Efficiency of transplanting oak trees for woodland habitat restoration*. unpublished draft.

Watson, Gary W. 1985. *Tree size affects root regeneration and top growth after transplanting.* Journal of Arboriculture 11:37-40.

Non-Pruned Coast Live Oak

All photos courtesy of the author



1996

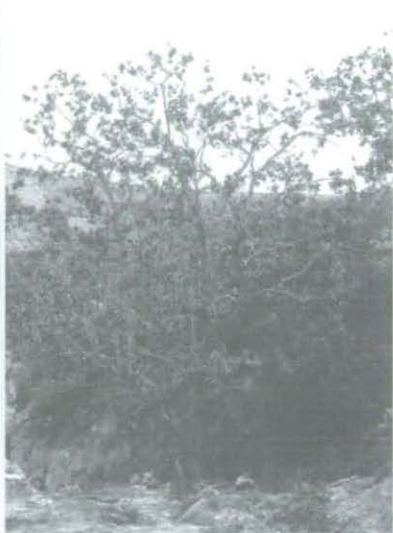


2001

Pruned Coast Live Oak



1993 Original condition



After pruning

Photographs of pruned and non-pruned transplanted coast live oaks (trees rated as stable)



2001 Present Condition

President Lincoln had initially thought of the Civil War in terms of preserving the Union. However as public outcry against slavery increased and Congress made steps toward abolition, Lincoln came around to embracing the emancipation of slaves. He finally came to the opinion that, "if slavery is not wrong, nothing is wrong."⁵ On September 22, 1862 Abraham Lincoln issued a preliminary proclamation stating that if the rebelling states did not return to the Union by January 1, 1863, he would declare their slaves "forever free". The Confederate government ignored this threat and Lincoln signed the Emancipation Proclamation on New Years Day 1863. It stated:

"And by virtue of the power and for the purpose aforesaid, I do order and declare that all persons held as slaves within said designated States and parts of States are, and henceforward shall be, free; and that the Executive Government of the United States, including the military and naval authorities thereof, will recognize and maintain the freedom of said persons.

... And upon this act, sincerely believed to be an act of justice, warranted by the Constitution upon military necessity, I invoke the considerate judgment of mankind and the gracious favor of Almighty God."⁶

The Emancipation Proclamation of 1863 actually freed relatively few slaves. The proclamation was limited to territories in rebellion and not to pro-Union border states or to southern states under Union control. Slavery in America would only be eliminated entirely with the passage of the 13th Amendment to the Constitution on December 18, 1865. The Emancipation did, however, shift the meaning of the Civil War for the North. Rather than simply an attempt to reunify the Union of States, the Civil War was now also a fight to eliminate slavery from the United States.

At the time of the proclamation, Hampton was under the control of the Union army and therefore the slaves living in the Hampton Roads area were not emancipated. Nonetheless, the proclamation was greeted with great celebration by African Americans. There was widespread confidence that the end of the Civil War would bring emancipation to all. Shortly after the issuance of the proclamation, hundreds more fugitive slaves from the Lower Virginia Peninsula, a rebel territory, gathered near the protection of the federally controlled Fort Monroe.

In 1868, the American Missionary Association purchased a farm adjacent to the Emancipation Oak and Brigadier General Samuel Chapman Armstrong founded a school to train selected African American and Native American men and women. Armstrong envisioned teaching the young people who would lead their fellow citizens by example toward a self sufficient and dignified future. In truth, this was a continuation of the work Mary Peake started alone, uncredited and in defiance years earlier on the very same site. In 1870, Armstrong's school was chartered as Hampton Normal and Agricultural Institute, today known as Hampton University. Hampton's most famous graduate was Booker T. Washington in 1875.

The Emancipation Oak, a national landmark, stands on the grounds of Hampton University and still serves as a shady outdoor classroom today.

Thanks to Victoria L. Jones, Director of University Relations, Hampton University for permission to photograph the Emancipation Oak. Photograph credits: Jeff Krueger 2003

References

- ¹ Clara Merritt DeBoer, *Blacks and the American Missionary Association*, www.ucc.org/aboutus/histories/chap6.htm, 1973.
- ² Tidewater Hall of Fame, www.nsu.edu/history/racetimeplace/HALLOFFAME2/Tidewater_hall_of_fame2.htm
- ³ Jonathon William Horstman, *The African-American's Civil War: A History of the 1st North Carolina*, Chapter 1, www.rootsweb.com/~ncusct/1stnccv.htm, 1998.
- ⁴ Jacquelyn Sparks, *The Freedmen's Bureau and African American Education during Reconstruction*, <http://thepinkflamingo27.tripod.com/Freedmenbureaupaper.htm>, 2001
- ⁵ George Tucker, "A Mighty Oak, a Monument to Freedom", *The Virginian-Pilot*, March 29, 1999.
- ⁶ Gerald Murphy, *The Emancipation Proclamation*, National Public Telecomputing Network, www.nps.gov/ncro/anti/emancipation.html.

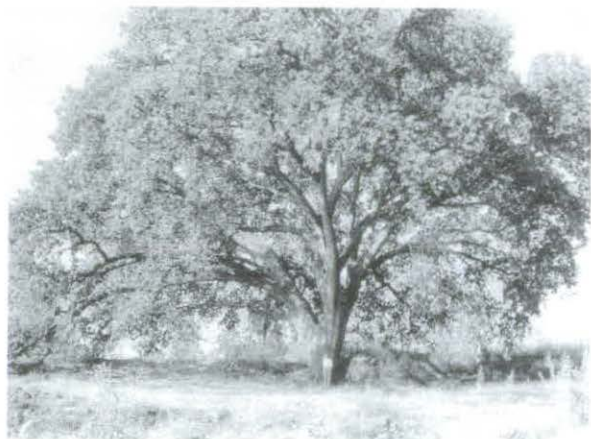
PROPOSED TREE REMOVAL GETS LOCAL RESIDENTS STIRRED UP

Doug McCreary, Editor, The International Oak Society

8279 Scott Forbes Road
Browns Valley, CA USA 95918

About 25 miles north of Los Angeles, in a Southern California community named Santa Clarita, a self-proclaimed environmentalist sat in a revered oak tree for over two months to try to prevent the tree from being cut down or moved. It was slated for removal to make way for a four-lane road that would serve new developments in the area. It all started on November 1, 2002, when John Quigley climbed the tree, named "Old Glory" by local schoolchildren, and set up his new home. He chose that date because it was when an agreement to save the massive valley oak, estimated to be between 400 and 500 years old, expired – an agreement between a local environmental organization (the Santa Clarita Organization for Planning and Environment or SCOPE) and a development company called John Laing Homes. Residents thought this

1999 agreement, stipulating that the developer would redesign the road-widening project to save the heritage oak, would protect the tree well into the future. But the developer indicated the agreement would no longer be honored and there were plans to remove the tree for the new road — a road they felt was necessary to accommodate the ever increasing



Old Glory (*Quercus agrifolia*)
Photo courtesy of SCOPE web site

number of people moving into planned housing developments in the area. John Quigley was recruited by SCOPE to sit in the tree and draw attention and opposition to the plan to cut down or move the tree. It worked wonderfully!

John's new home in Old Glory was the subject of countless media stories and he became a celebrity of sorts. There were dinners under the tree, as well as block parties when residents came to encourage John and get together and demonstrate their support. School children visited the site and put up posters on a nearby fence. There were also news conferences, celebrity appearances and even an emergency dentist appointment for John!

John Laing Homes came up with another idea. They proposed that the tree be moved to another nearby location and hired Valley Crest Tree Company to com-

plete the job. They were even willing to absorb the cost, estimated at several hundred thousand dollars. But SCOPE felt the plan had little chance of success and quoted arborists who doubted that a tree of that size could be moved without killing it. While smaller oaks have been moved previously, movement of a tree this size has never been attempted before, and SCOPE pointed out that even smaller trees that have been moved in the past often haven't fared well (See article *Oak Transplantation: does this really save the trees?* in this issue). So the battle lines were drawn.

SCOPE proposed that the road in question be downsized from 4 lanes to 2 lanes and that a linear natural park in the area around Old Glory be created to ensure that the tree was protected. But when a group of supporters, led by actress Rene Russo, presented the alternative roadway alignment plan to the County Supervisor's office, it was not accepted. The County claimed that other alternatives were already being examined, but none were acceptable. On Christmas Eve the County reiterated that the road was necessary and the tree must be cut down or moved.

In late December, Valley Crest decided it would not participate in moving the tree, citing harassment and threats as a reason. Certainly it was beginning to be a public relations nightmare for the company. And John Quigley announced that in the beginning of January he would come down from the tree, but that replacement tree-sitters would take up his post. But on Friday, January 10, before John had left, a judge issued an eviction order demanding that he vacate the tree he had been living in for over two months. Authorities serving the order broke a device that John was using to chain himself to the tree, and then peacefully escorted him to the ground. He was not arrested. Two days later, workers arrived and began preparing the tree for a move to a nearby park. Ditches around the tree were dug and the tree-moving company began to fertilize the roots to stimulate growth. The tree has not yet been moved to its new home. Only time will tell if the tree can survive.

THE PEMBERTON OAK

Mike Dahl

Overmountain Victory Trail Association
P.O. Box 242421
Charlotte, NC 28244

Editor's Note: At about the same time the last issue of International Oaks was going to the printer, which contained an article about the Pemberton Oak and the Overmountain Men, the old tree finally came crashing to the ground, ending its lengthy and historically significant life. Below are portions of a message that several members of the International Oak Society received the day after the tree fell from Mike Dahl, the author of the article titled Spaces Between the Footsteps: The Pemberton Oak that appeared in the last issue of International Oaks (Volume 13).

Hi All,

Many of you have heard the news by now. Many have not. Yesterday, August 1, 2002, a little after 1:00 PM, the Pemberton Oak fell. Completely. Sue was sitting at the table inside the house and heard a loud crack. Then a crash. She knew what it was when she heard it. The old white oak had fallen.

There is about 12 to 15 feet (4-5 m) of vertical stump left—up to where the lateral branches started. It was obvious from seeing the split ends of those massive laterals that the heart rot had extended up to that point. All that supported the tree and the laterals these last several years was about 3 to 4 inches (8-10 cm) of wood. The rest of the tree's center was hollow. There are no branches at all remaining. Only the lone column of the tree's bole.

Allen Ray called me last night with the news. I passed it on, as did many others. One of the people I contacted was Jim Cortese who owns Cortese Tree Service here in Knoxville. He had met with Sue Vaughan, owner of the tree's property, back this spring to get permission to nominate the Pemberton Oak for Tennessee's Heritage Tree program. Jim said he had received the letter making the designation in yesterday's mail. Jim also said that the horticulture department at the University of Tennessee was doing some leading edge genetic research on "cloning" trees from live cuttings.

On the way up to the Oak this morning, I called Martin Miller of the Tennessee Division of Forestry. Martin is the forester who inspected the tree back in 1997, discovered it was hollow, and who provided the maintenance prescription for spraying and fertilizing we have been following. Martin was devastated to hear the news and said he would cancel everything he had scheduled for the day and meet me at the tree. Martin arrived about 10 minutes after I did. I told him about the UT genetic research and we worked together taking cuttings, putting them in moistened bags and in a cooler I'd brought for the purpose.

The tree did no damage to the house. However, the large limbs on the backside took out the power and phone lines when they fell. Sue's power is back on, but her phone service is still out. Only one limb fell towards the front—towards the road. That limb took out a short section of the boxwoods and got into the magnolia on the

left side of the boxwoods. Several dogwoods and smaller trees on the right quarter rear side of the tree were smashed.

Blair and I talked to Sue about getting some logs 6 to 8 to 10 feet (2-3 m) long cut off from the large lateral limbs (the ones that pointed towards the back of the property were the largest and straightest) to use for commemorative pieces and blocks to raise money for the Trail. Bless her heart, she had already told people who had asked for wood that OVTA (Overmountain Victory Trail Association) got first take. Blair said he had a friend who had a large band saw and his son has a flat bed truck. He would talk to them and come back Monday to get the logs and haul them to the sawmill.

Then about 11 o'clock the neighboring men started arriving. A dozen maybe. They came in pick-ups. One came in a dump truck. One came driving a large farm tractor with a scoop and pallet forks on the front. They all brought chain saws. They went to work. First the limb on the front side. Cut up. Leaf ends picked up first and put in the truck and then hauled out in the field and dumped to be burned when they dry. They will warm someone's house this winter.

I got a fair load of smaller cut pieces loaded in the back of my truck. Had to dodge around the neighbors helping to clean up. Kind of a gentle reminder of days lost and past watching how the neighbors dropped their own duties and tasks to come help clear the tree away. But I am sure they looked at it differently than I did. They were just out helping a neighbor clear a mess out of her yard. I saw it as something else. Sometimes while lugging those pieces of the tree to the truck I had trouble distinguishing whether it was sweat or whether it was tears burning my eyes as I carried each



Pemberton Oak (*Quercus alba*)
Photo courtesy of Leigh Van Blarcom

piece, one at a time, and laid it in the back of the truck. I got several smaller limb pieces in the 2 to 4 inch (5-10 cm) diameter size a foot or two long. Got a few pieces in the 6 to 8 inch (15-20 cm) diameter range also. Got one about 16 inches (41 cm) thick. And one...BIG ONE. Took two of us to lug it to the truck.

I left a little after noon. Just couldn't watch the saws any more. Besides. I had another stop to make. Needed to find Lester's grave. Had to tell him the tree had fallen. And now, my own words...for the tree.

For five hundred years, the Oak has stood. Five hundred winters. Five hundred times it has endured the scorching heat of summer and the vicious winds of March. More than six thousand times the full moon has risen over the mountains on the eastern horizon and gave a ghostly light that danced over the Oak's leaves and branches. For more than half those years, only animals passed by; maybe an Indian hunting party or two, but not many. Nothing more than that to mark the passage of time. The passage of the years.

And then the white settlers came and things changed. New men with the desire to claim and improve and defend the land. John Pemberton was the first. Time now had a measure beyond the passing of the seasons. The years could be counted now by the new buildings, the adding of livestock, new fences, new children's voices who danced in the shade and climbed all the way to the heavens. An old woman came by today to visit with Sue. They had grown up together. They had been little girls together so many, many years ago. She spoke of those years and those days dancing in the yard and feeling alive and free under the great branches of the Oak.

It has stood. Tall, regal, commanding. It has stood. Until yesterday. And then, it let go. The time, the years, the insidious rot from within that was more than the tree could withstand. It stood. Until yesterday. And then...it fell.

And now there remains this hollow tower. By tomorrow the ground-born signs of the falling will be gone. The limbs and leaves will be cut and carried away by the neighbors. The ground will show the scars of tractor and truck wheel and the scars of the massive weight of the limbs crashing down. But only the stump will remain. We cannot repair. We cannot rejuvenate or renovate or reconstruct. We cannot remedy this falling. It is final. It is forever. But in the falling, we can remember and we can hold reverence for the last living artifact of the Overmountain Men.

The Pemberton Oak has fallen. It too, like Lester, like Tom Gray, like Bill Stronach just two month ago, has fallen and taken its place in the spaces between the footsteps of the Overmountain Men.

I close now.
The Tree has fallen.
But the Story goes on.
As it must.

- Mike

THE MAJOR OAK, SHERWOOD FOREST, ENGLAND

By John Palmer,
Dorset, England

Introduction

This giant tree, weighing an estimated 23 tons with a waistline of 33 ft (10 m), has been growing in Sherwood Forest for about 800-1000 years. The exact age of this magnificent tree can only be estimated, however, since it is hollow in the center, preventing an accurate assessment of its true age. Its huge size is a clue, although it is well known that not all oaks grow at the same rate.

Its large canopy, with a spread of 92 ft (28 m), points to it being a tree that has grown up with little or no competition from oaks nearby. This has allowed the large branches and network of leaves to spread out. Its huge trunks formed as the tree's demands for food, water, and structural support increased during its continued growth, as it still does today.

The Domesday Book, compiled by William the Conqueror in 1086 to assess the lands and resources of England, noted that Sherwood Forest covered most of Nottinghamshire above the River Trent. Large trees were seen as a medium of prophecy and knowledge. These trees were associated with woods like Sherwood. Large oaks were frequently depicted as dwelling places for woodland spirits and legend has it that Robin Hood hid from his enemies inside the Major Oak.



The Major Oak (*Quercus robur*)
Photo courtesy of the author.

Natural History

The Major Oak is listed as being an English or pedunculate oak (*Quercus robur*). Its leaves begin to grow in April-May and stay on until October-November, depending on the severity of the first autumn frosts. The tree's flowers, small male catkins and the much smaller female flowers with dark stigmas, are produced soon after the leaves have opened.

The acorns of the pedunculate oak grow on stalks and they mature in late October. Generally the tree has a good acorn crop, sometimes known as mast, every 2-3 years. Good acorn crops only occur in the years when the spring weather is warm and dry enough to allow the oak flowers to be wind pollinated successfully.

The oak's great hollow interior is not man-made; it is actually caused by fungi, the most invasive of which is called the "poor man's beefsteak" (*Fistulina hepatica*), whose fruiting bodies are sometimes seen growing on the bark of the tree during the autumn.

Like all other oaks, the Major Oak provides plenty of food for caterpillars and insects; its deeply fissured bark furnishes them with many hiding places, giving much needed protection from predators.

The Major Oak's enormous interior is also useful for hibernating insects and mammals such as bats, queen wasps, butterflies and a variety of spiders. All make use of the valuable protection and shelter the tree has to offer during the harsh winter weather.

In the Spring, many birds, including jackdaws, woodpeckers and great tits make their nests in what is Sherwood's most famous oak. Look out for young grey squirrels in May-June, as they make their first journeys away from their nests; you can often see them practicing their tightrope acts on the oak's network of supporting cables.

So, not only are these ancient oak trees inspirational in their beauty, majesty and spiritual qualities, they are also unrivalled as natural habitats among the many species of woodland trees. Each one is an individual nature reserve; it can act as host to over 32 species of mammals, 68 species of birds, 34 species of butterflies, 271 species of insects, 168 species of flowers, 10 species of ferns, and 31 species of fungi or lichen. Amongst them all stands the Major Oak, a giant in all respects and worthy of a place in all our hearts.

An Accident of Nature?

There are several theories as to what caused the tree to grow into the size and shape it is today. One is that the Major Oak may in fact be more than one tree! Perhaps as a consequence of a chance germination of several acorns some 800 years ago, three or four trees began to grow close to one another. The tree we see today is the product of these young saplings fusing together as they grew to form one enormous oak. There are large grooves visible on the outside, and the hollow interior is actually several open chambers combined together, which is evidence that this is a possibility. Genetic testing could determine if this is, in fact, the case.

Another theory is that the tree has been pollarded. This was a system of tree management that enabled the foresters to grow more than one crop of timber from a single tree. Pollarding, or cutting back the top, was repeated every 40-50 years, causing the trunk to grow large and fat, the tops of which became swollen after several centuries of this cropping. This system of management allowed trees to grow longer than unmanaged trees. Some have been found to be 1000 years old. This tree was probably spared from the final forester's axe because of its hollow rotted trunk. The tree was probably spared also because of its landscape and heritage value. Romantic stories of Robin Hood only added weight to the case for the tree's preservation.

Care and Management

The Major Oak received special attention throughout the 20th century. In 1908, metal straps and chains were installed high up in the canopy to support the weakest branches. Large holes were covered in lead sheeting to prevent rain entering, but unfortunately this was later removed by some distant relatives of Robin's merry band. Supports in the form of wooden poles were also first used for support about this time.

By 1972 the pressure of thousands of visitor's feet (220,000 per year) was beginning to take its toll, causing the upper branches to die back; soil compaction prevented rain water and minerals from the leaf-litter decomposition to percolate down to the roots nourishing the tree.

In 1975 when the new Visitor Centre was built by Nottinghamshire Council, a fence was installed around the great tree, preventing further damage from the ever

increasing number of visitors to Sherwood. This fence kept visitors away from the tree, helping to save it for the future, as it still does today.

A tree company (Tree Surgeons) was brought in to treat the tree by removing decaying branches, covering up gaping holes, replacing some of the old chains and straps, and giving the exposed wood, both inside and outside, a coat of arboricultural paint to prevent further decay. However, a complete eradication of fungi can prove almost impossible and fruiting bodies can sometimes be seen on the tree in the autumn¹.

In the mid 80's more supports were added, preventing sideways, horizontal movement of the larger lower limbs. In 1994 the grass under the tree's canopy, which had originally been introduced for aesthetic purposes, was removed to prevent it from competing with the tree for nutrients. An inert mulch was then spread to prevent the soil from drying out. Outside the "drip circle" the natural regeneration of the woodland flora is being allowed to grow back. The tree is now inspected on a daily basis by the ranger staff, whilst Tree Surgeons visit the site on a seasonal basis to check the oak for routine maintenance and feeding.

With your support and respect, this grand old tree may live for many years to come. But, it may be remembered that the Major Oak, even guarded by the spirits of the greenwood and Robin Hood, is not immortal.

Local History

It is probable that this ancient tree was named after a local historian. The Major Oak's first recorded name was the Cockpen Tree; this was with reference to its earlier use as a cockerel pen during the mid-18th century. The unfortunate game birds were stacked inside the tree in wicker baskets, or just tied in hessian sacking, before they were taken out and mercilessly thrown together for this barbaric sport.

The tree did not become well known until about 200 years ago when in 1790 the tree was described by Major Hayman Rooke FSA, who was a local historian from the Mansfield area. In the same year, he published a book entitled "Remarkable Oaks in the Park of Welbeck in the County of Nottingham." It was soon after this that the tree was named after him. Its name means "The Major's Oak" and not the largest oak.

Throughout the last century, it was also known as the Queen or Queen's Oak. There is no known connection with any Royal figure - this name probably just described its large size and its status as Lady of the Forest, because it was such a majestic tree.

A Tourist Attraction

In Victorian times, the Major Oak became a popular visiting place, although it was always well known by local people. People visited the tree, coming to Edwinstowe by train and then by carriage, to see the tree. More than 600,000 people from all over the world coming to visit this venerable giant each year.

Whilst this tree is not the largest in girth in the country, it is certainly the most famous, surrounded by mystique and folklore. We hope that it will continue to be so for many years and provide a joy to see for people from all over the world in this ancient forest of Sherwood.

Editor's Note: The author of this article is John Palmer, who is the webmaster of the Major Oak web site (<http://www.wirksworth.org.uk/majoroak.htm>), where

you can obtain additional information about this magnificent tree.

John has also informed us that he recently bought 25 acres of pastureland in Dorset and intends to create a "New Sherwood Forest" there using saplings grown from acorns collected from underneath the Major Oak in the Millennium year. There are currently more than 300 saplings growing in 10-litre pots in his back yard that are earmarked for a 7-acre field, and he hopes for more in the future. Through research at his local County Record Office, he found a Tithe Map dated 1813 which names these fields as "Great Wood" and "Little Wood," although today there is no sign of trees, except in the hedges. He also hopes to include other tree species in the planting, including ash and alder.

This proposed planting site is also close to a Roman Fortress, which was built in 45 AD when the 2nd Augustan Legion under Vespasian invaded the British islands. The Romans would have needed a large quantity of stout timber growing close at hand to construct their fortress, house their men, and build giant catapults to attack the huge British Hill Forts nearby. The Roman invasion was successful, and British history was changed forever.

¹Arboricultural practices vary and some of these procedures might not be universally accepted as the best way to protect old trees. For example, the use of "arborist paint" is not necessarily endorsed by the International Oak Society as the most effective practice (Editor).

STORM TOPPLES WYE OAK

Frank D. Roylance and Chris Guy.

Editor's Note: Material for this article was taken from the Maryland Department of Natural Resources Forest Service web page (<http://www.dnr.state.md.us/>). A quote from the Editor of American Forests Magazine is also included.

On June 6, 2002, Maryland's oldest living tree, the majestic 460-year-old Wye Oak, was felled during a violent thunderstorm on the Eastern Shore. The massive tree, which stood almost 100 feet (31 m) tall, and had a crown spread of nearly 120 feet (36 m), and a trunk diameter of close to 10 feet (3 m), was a National Champion — the largest recorded living white oak (*Q. alba*) known — and one of the most famous trees in the United States. It came down across Route 662 in the tiny village of Wye Mills, Talbot County, Maryland. Work crews immediately began to remove the huge limbs and clear the road.

The tree had been growing in Wye Mills since the 1500s, nearly a century before Europeans came to Maryland. It had survived countless storms, disease, insects, air pollution and road paving and had witnessed the birth of a nation. Early in its life Native Americans lived and hunted in the area and an ancient path called the Choptank Trail passed close by. Later, the tree's branches provided shade to early settlers who were traveling through. In the 19th Century it was called the Russum Oak. By the early 1900's that name was changed to the Wye Oak, after the village of Wye Mills.

In 1909, the then gigantic tree was first officially distinguished for its size. Maryland's first State Forester measured and photographed the tree and many people began to consider it the largest white oak in the state and, for the first time, visitors came to view its sweeping boughs. Ten years later, the American Forestry Magazine honored the Wye in its Tree Hall of Fame and launched what would later become a national search for Big Tree Champions. Until it fell, the Wye Oak held the title of largest white oak in the United States. It was one of only two trees to remain national champions since the American Forestry Association began its contest in 1940.

In 1939, the State of Maryland purchased the Wye Oak from its last private owner "in accordance with our desire to preserve places of historical and outstanding interest," said Governor O'Connor. Soon after, the Legislature declared the Wye Oak the living symbol of the State Tree, the white oak. The Wye Oak State Park was established — the smallest State Park in Maryland — and marked the first time a government purchased a single tree for preservation.

In spite of efforts to save the tree by pruning, cabling, and installing lightning rods, the Wye Oak's time had finally come. Reactions were swift and deeply felt. "It's like a little piece of everybody's life went down with it," said Gail Dadds, who grew up less than a mile away and went to view its remains the night it fell. "I've lived around this tree for most of my life. It's so sad to see it like this." State highway workers roped off the area with yellow crime-scene tape. But dozens of people came to view the fallen giant and collect souvenirs and take photographs. Jennifer Reburn, a local second-grade teacher, stooped to gather sticks, twigs and leaves. She was already thinking how she would explain the death of the tree to her students who had visited the Wye Oak last month. She was sure they would be devastated by the loss.

Frank Gouin, a retired former chairman of the horticulture department at the University of Maryland, produced the first successful clones of the tree two years ago. After hearing the news, he indicated how much he loved that old tree. He promised that he would collect bud wood and produce as many clones - genetically identical oak saplings - as possible. Some of the clones that are currently growing will be planted in the same tiny park where the old tree went down. Already, Wye Oak clones have been planted at Mount Vernon, George Washington's home in Virginia.

State officials said they were unsure whether the Wye Oak was struck by lightning, succumbed to high winds, or both, as the band of severe storms raced through tiny

Wye Mills. "One guy said he saw lightning, somebody else thought it was the wind," said Stark McLaughlin, a Department of Natural Resources forester. "Either way, it's totally gone now. It even had acorns this year. But we've known for a very long time that, even doing everything humanly possible, we couldn't save it."

Maryland Governor Parris N. Glendening issued a statement: "For more than 450 years the Wye Oak has stood strong and tall, surviving winds, drought and diseases of nature, and even more remarkably the human threats of chain saws and global warming. 'Someone once wrote that 'a tree is a child of the earth, and to the earth it must inevitably fall.' There is some comfort tonight that in the case of our beloved Wye Oak, nature has had the last say."

Editor's Note: After the Wye oak fell, Michelle Robbins, Editor of American Forests Magazine wrote the following:

"Everybody thinks about the change of skyline with the WTC, but no one seems to mention it when it comes to landmark trees. The Wye Oak had special meaning for me — I grew up on the Eastern Shore and it's hard to describe just how important that tree was to people from there. I remember being taken on a bus trip in elementary school to see it. I used to tell people around here that if you're from the Eastern Shore, you put your hand over your heart when anyone mentions the Wye Oak. We have one of the offspring in our backyard, planted just after our oldest (now 8) was born. It still breaks my heart to see it gone. The difference in the skyline at Wye Mills now, well . . ."



An historic photo of the Wye Oak, taken in its prime, its branches shining with ice.

Photo courtesy of Michelle Robbins, Editor, American Forests.

A GALLERY OF SOUTHERN LIVE OAKS

Guy Sternberg^a and William Guion^b

^aStarhill Forest, Petersburg, IL USA

strhlfrst@aol.com

^bMonterey, CA USA, william_guion@ctb.com

A cross section of *Quercus virginiana* from throughout the Deep South of the United States is presented in this photo gallery by Guy Sternberg and Bill Guion.



Angel Oak (St. John's Island, South Carolina)

Photo copyright Guy Sternberg



Anseman Oak (New Orleans, Louisiana)

Photo copyright Guy Sternberg



Enrique Alferes Oak (New Orleans, Louisiana)

Photo copyright Guy Sternberg



Majestic Oak (Savannah, Georgia)

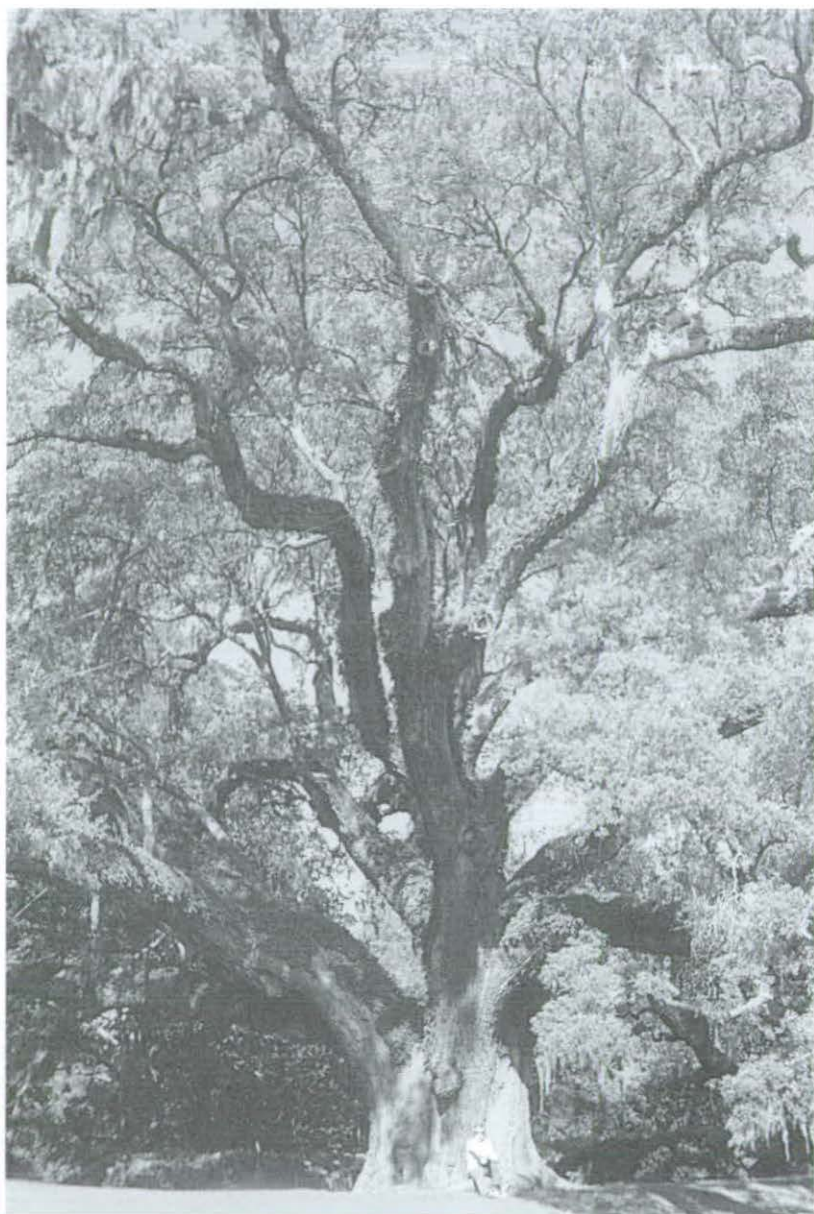
Photo copyright Guy Sternberg



McDonogh Oak (New Orleans, Louisiana)
Photo copyright Guy Sternberg



Evergreen Plantation (Edgard, Louisiana)
Photo copyright William Guion



Middleton Oak (Charleston, South Carolina)
Photo copyright Guy Sternberg



Brothers Oaks (Bayou Lafourche, Raceland, Louisiana)

Photo copyright William Guion



Abbot Schaeuble Oak (Covington, Louisiana)

Photo copyright Guy Sternberg



Red Church Oak (Reserve, Louisiana)

Photo copyright Guy Sternberg



Afton Villa Plantation (St. Francisville, Louisiana)

Photo copyright William Guion



Five Oaks in Grove (New Orleans, Louisiana)

Photo copyright William Guion



Oak Alley gate (Oak Alley Plantation, Vacherie, Louisiana)

Photo copyright William Guion



Josephine Oak (Oak Alley Plantation, Vacherie, Louisiana)

Photo copyright William Guion



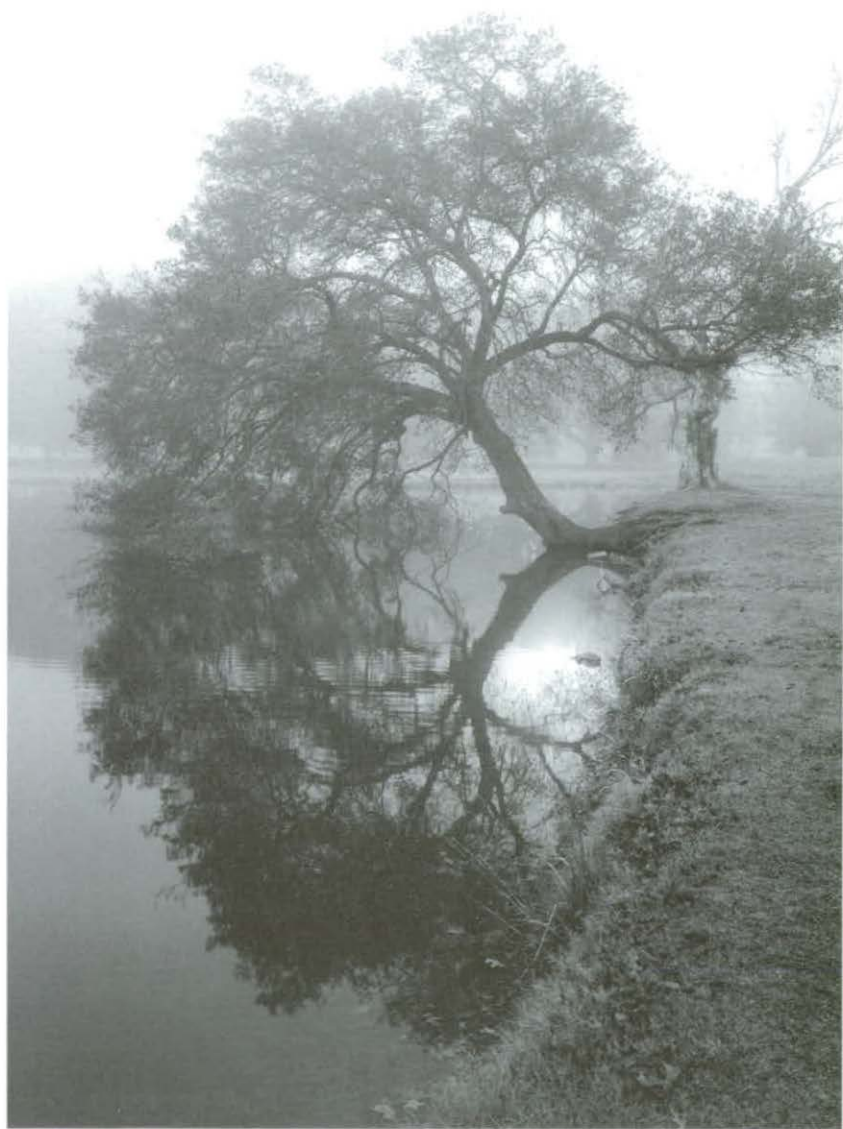
Rosedown Plantation (St. Francisville, South Carolina)

Photo copyright William Guion



Oak Alley, roots (Oak Alley Plantation, Vacherie, Louisiana)

Photo copyright William Guion



Leaning Oak (New Orleans, Louisiana)

Photo copyright William Guion



Boone Hall Plantation (Mt. Pleasant, South Carolina)

Photo copyright Guy Sternberg



Cavu
(Burton, South Carolina)

Photo copyright Guy Sternberg



Ormond Plantation (Reserve, Louisiana)

Photo copyright Guy Sternberg



Ormond Oak (Montz, Louisiana)

Photo copyright Guy Sternberg



Live Oak Flowers (St. Francisville, Louisiana)

Photo copyright Guy Sternberg



Seedling in Pine Needles
(Pinckney Island,
South Carolina)

Photo copyright Guy Sternberg



Drayton Hall Plantation (Charleston, South Carolina)

Photo copyright Guy Sternberg



Greenleaves (Natchez, Mississippi)

Photo copyright Guy Sternberg



Highlands Hammock State Park (Florida)
Photo copyright Guy Sternberg



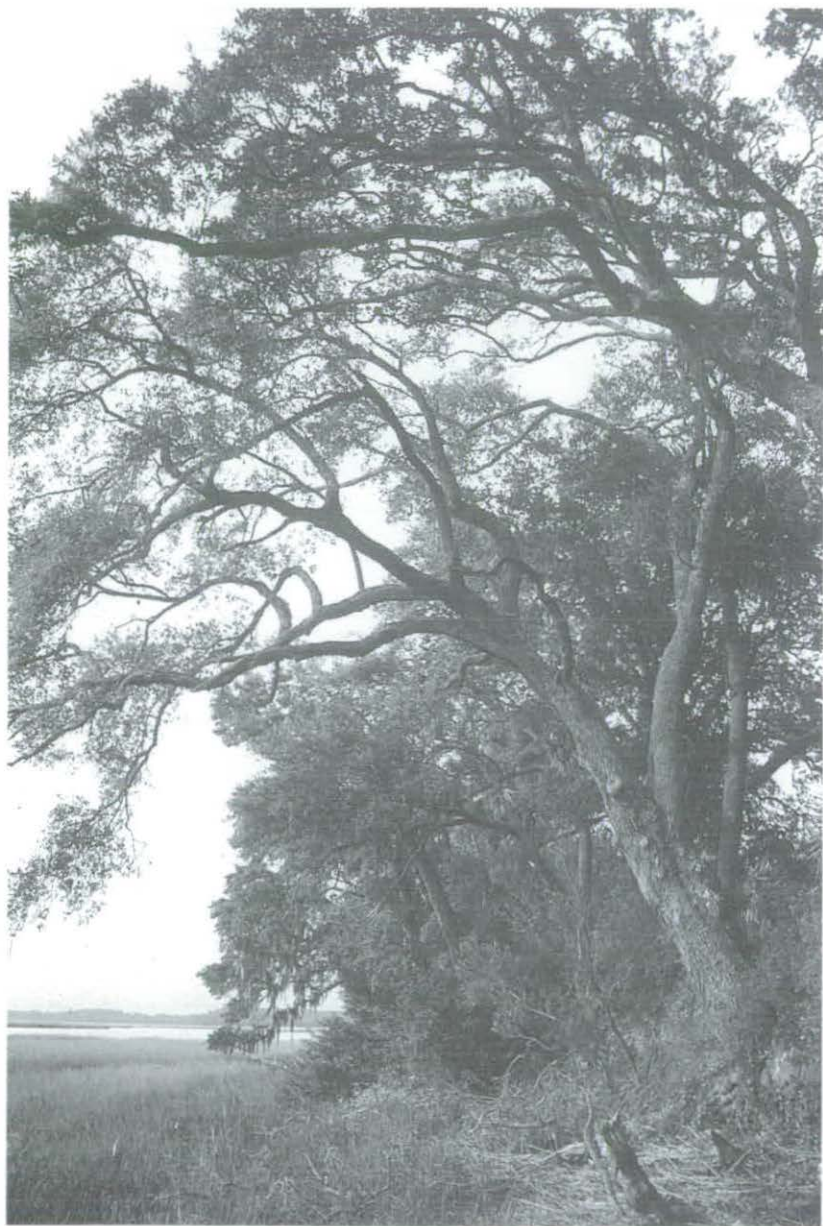
Live Oak Roots (Pinckney Island, South Carolina)

Photo copyright Guy Sternberg



Live Oak Root detail (Pinckney Island, South Carolina)

Photo copyright Guy Sternberg



Tide Marsh (Pinckney Island, South Carolina)

Photo copyright Guy Sternberg

NEW OAK HYBRIDS FROM SPAIN

Francisco M. Vázquez, Soledad Ramos and Esperanza Doncel

Department of Forest Production, SIDT-EXTREMADURA,

Avd. de Portugal s/n 06800 Mérida (Badajoz), Spain

Allen J. Coombes,

Sir Harold Hillier Gardens, Jermyns Lane, Ampfield, Romsey, Hampshire

SO51 0QA, United Kingdom

Maricela Rodríguez-Coombes,

Herbario y Jardín Botánico, Benemérita Universidad Autónoma de Puebla, Avd. San Claudio s/n. C.P. 72590 Puebla, Pue. México. Current address: Biodiversity and Ecology Department, School of Biology, University of Southampton, Bassett Crescent East, Southampton, Hampshire SO16 7PX, United Kingdom.

Introduction

Much work has been carried out on hybridization in oaks (Benson, 1962; Hardin 1975; Muller, 1951; Palmer, 1948 and Stebbins, 1950). In Europe, and in the Mediterranean region in particular, work has been intensive, not only because of the diversity of species and the ease with which they hybridize, but also because of the decrease in area of the original forests. This has resulted from an increase in agriculture and forestry which has facilitated hybridization (Vázquez et al., 2000; Vicioso, 1950).

In the Iberian Peninsula there are many species of *Quercus* (about 15 according to Amaral, 1990), and more than 20 different known hybrids, as well as infraspecific taxa. Hybridization occurs between these according to geographic proximity, climatic conditions, and phenological variations between species in the same habitat (Cottam et al., 1959; Muller, 1952; Vázquez, 1995).

In addition to the above, modification of the habitat by man, followed by the introduction or colonization of new species in old habitats, are important factors in the formation of some of the new hybrids not known until recently.

Considering the ecological changes and the interest in, and importance of, *Quercus* in the Iberian Peninsula, we felt it was important to carry out work on oak hybridization and to gain more knowledge of the morphological variation of different oak species and the ecological conditions under which they grow.

The objective of this paper is to present the results of field work carried out over the last three years on oak hybrids and their distribution in the Iberian Peninsula.

Methodology

Field trips were made to various parts of the Iberian Peninsula during 1999, 2000, and 2001. In order to make accurate identifications, material collected was compared to descriptions of *Quercus* from the Iberian Peninsula (Coutinho, 1888; Vicioso, 1950; Carvalho & Amaral, 1954; Amaral, 1990; and Rivas Martínez & Saenz 1991) and from adjacent areas of North Africa (Battandier & Trabut, 1890; Camus, 1936-39).

Material not identified previously was studied more intensively in order to identify it correctly and to describe it as a new taxon (nothotaxon). This was carried out using morphological characters and by studying foliar trichomes (Hardin, 1979; Llamas et al., 1995; and Thomson et al., 1979).

Results

New oak hybrids found during this work are described below, as well as a new location of an existing hybrid.

Quercus x diosdadoi F.M. Vázquez, A. Coombes, M. Rodríguez-Coombes, S. Ramos & E. Doncel *nothosp. nov.*

= *Quercus pyrenaica* Willd. x *Quercus rotundifolia* Lam.

Latin Description:

Arbor cum folia subcoriacea; lamina (2-)3-5,5(-6,5) cm longa et (1-)2-3,5(-6) cm lata, supra stellato pubescente vel glabrescente, subtus grisacea, pilis stellato et fasciculatis, tomentosa; ambitu oblonda aut oblongo-lanceolata, apicem obtusata vel breviter acuta ex basi cordata aut inaequalia; sinuato-lobulata vel entera, lobis triangularibus, acutis et cum spinis. Costae laterales utrimque 4-7 angulo acuto, nervis sinuatis frequentibus. Petiolus tomentosus (0,7-)1-1,7(-2) cm longus.

Floribus solitarius vel 3-5 in racimus cum pedúnculo tomentoso, 0,3-0,8(-1,2) cm longus.

Fructus cum cupula hemisphaerica, extus tomentosa, glandem includens squamis planis oblongo-lanceolata, cum apice obtusis.

Holotypus: HISPANIA: Cáceres, Naval Moral de la Mata, La Bazagona, 14-V-2000, E. Balbuena, J. Pera, X. Parladé, J. Luque et F. M. Vázquez. HSIA 4861.

Isotypus: Harold Hillier Herbarium (s.n.)

Dedicata Diosdado Simón Villares (195?-2002), horticultor et amicus.

Description:

Tree to 8-m tall. Leaves coriaceous; lamina (2-)3-5.5(-6.5) cm long and (1-)2-3.5(-6) cm broad, abaxial surface tomentose, adaxial surface pubescent, lanceolate to oblong, sinuate-lobulate or entire at the margin with short, triangular, obtuse to acute, spine-tipped lobules to 0.6 cm long, secondary veins sinuate; petiole pubescent, (0.7-)1-1.7(-2) cm long. (See Figure 1.)

Plant fertile. Male inflorescences (catkins) to 5.5-cm long, pubescent, the many flowers with ciliate and pubescent scales. Female inflorescence (raceme) short or long, with 2-12 flowers; style short with pubescent apex. Fruit solitary or in racemes of 3-5, peduncle 0.3-0.8(-1.2) cm long, tomentose to pubescent. Cupule subspherical, scales tomentose, oblong-lanceolate, obtuse and free at the apex. Acorn half included in the cupule, subspherical to spherical, up to 1.5-cm long and 1-cm wide, brown and glabrous.

Ecology: Occurs in the acid soils of southwest Spain, close to the Gredos Mountains in the Extremadura region. Mixed populations can be found in cork oak (*Q. suber*) and Pyrenean oak (*Q. pyrenaica*) dominated forests with sporadic *Q. rotundifolia*. The climate in this area is characterized by high humidity, moderate rainfall and frequent frosts in winter.

Distribution: Endemic to Spain, probably only in the Gredos Mountains in the Central Iberian Peninsula.

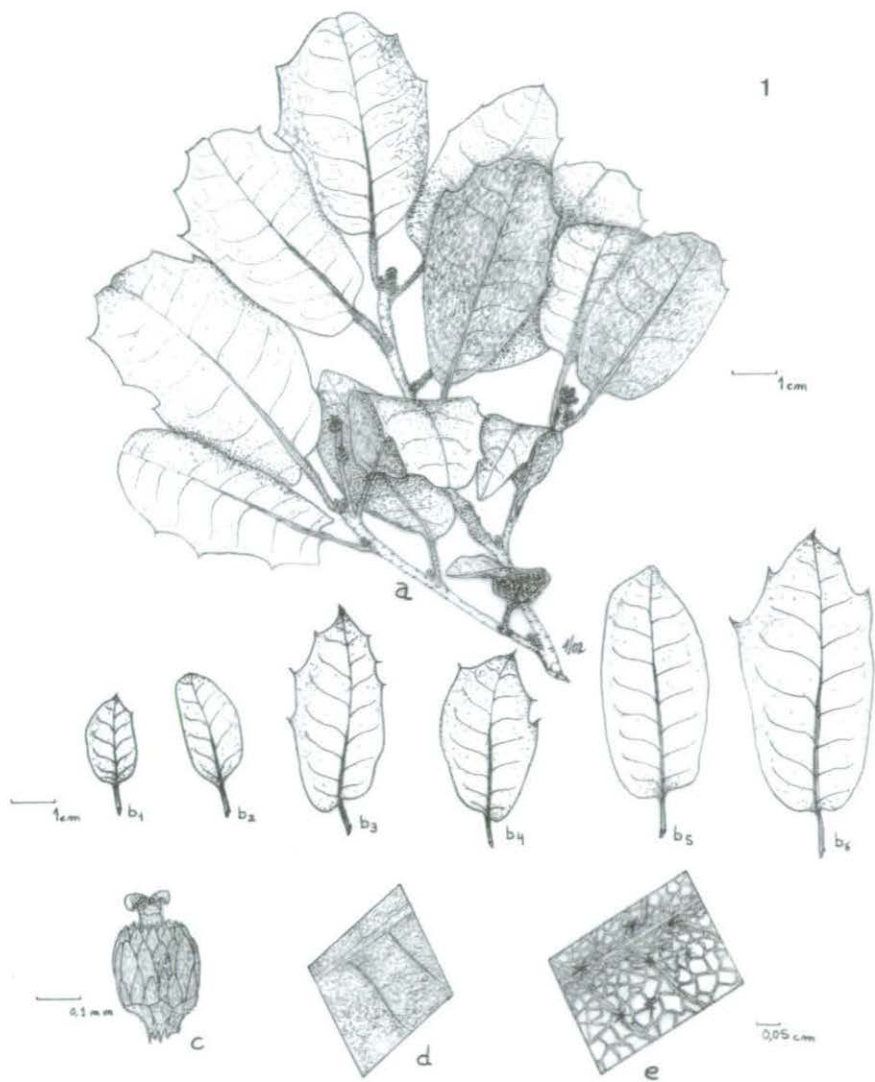


Figure 1. *Quercus x diosdadoi* F.M. Vazquez, A. Coombes, M. Rodríguez-Coombes, S. Ramos & E. Doncel, from the type collection. a: small shoot, b1 to b6: leaf types, c: female flower, d: abaxial surface, e: adaxial surface

The principal differences between this hybrid and its parents are shown in *Table 1*.

Table 1. Principal differences between *Quercus x diosdadoi* and its parents *Q. pyrenaica* and *Q. rotundifolia*.

Character	<i>Q. pyrenaica</i>	<i>Q. x diosdadoi</i>	<i>Q. rotundifolia</i>
Leaf morphology	Subspathulate	Oblong	Oblong, rotund
Leaf margin	Lobulate to pinnate	Entire to lobulate	Entire
Marginal spines	Absent	Absent or present	Absent or present
Petiole length mm	(6-)8-22(-35)	(7-)10-17(-20)	(3-)5-10(-12)
Cupule scales	Lanceolate	Oblong-lanceolate	Ovate
- Pubescence	Dense	Dense	Dense
- Position	Free	Free	Imbricate
- Apex	Acute	Obtuse	Obtuse
Foliar trichome types			
Simple-uniseriate	Absent	Present	Present
Bulbous	Absent	Present	Present
Solitary	Present	Present	Present
Fasciculate	Present	Present	Absent
Multiradiate	Present	Present	Absent
Stellate	Present	Present	Absent
Fused-stellate	Present	Present	Present

Quercus x celtica F.M. Vazquez, A. Coombes, M. Rodríguez-Coombes, S. Ramos & E. Doncel nothosp. nov.
= *Quercus lusitanica* Lam. x *Quercus suber* L.

Latin Description:

Frutex cum folia coriacea; lamina (3-)4-8(-9,5) cm longa et (2-)3-5,5(-7) cm lata, supra initio pubescens vel glabra sat cito glabra, subtus minimus tomentosa vel glabrescens et glabra; ambitu lanceolata vel aut spatulata, apicem acuta vel rotunda ex basi cordata aut inaequalia; serratis vel sinuato-lobulata, lobis ovato-triangularibus, acutis et cum mucronis. Costae laterales utrimque 3-5(-7) angulo acuto, nervis sinuatis. Petiolus tomentosus 0,2-0,8 (-1) cm longus.

Plantae steribus, cum floribus solitariis et pedunculo tomentosis, 0,3-0,7 cm longus et cum cupulae minimus sem glandem.

Holotypus: LUSITANIA: Alentejo, Ponte do Sor, Ervideira, 21-XI-1999, F. M. Vázquez. HSIA 3718.

Isotypus: Harold Hillier Herbarium (s.n.)

Description:

Shrub to 2-m tall. Leaves coriaceous; lamina (3-)4-8(-9.5) -cm long and (2-)3-5.5(-7) -cm broad, adaxial surface tomentose, abaxial surface glabrous to subglabrate, lanceolate to oblong, margin serrate to sinuate-lobulate with triangular lobes acute and obtusely mucronate at the apex, secondary veins sinuate; petiole pubescent, 0.2-0.8(-1) -cm long.

Plant sterile. Male inflorescence (catkins) up to 6-cm long, pubescent, the small

flowers with ciliate scales. Female inflorescence (racemes) short, with 1 to 4 sterile flowers, the style long with a pubescent apex. Without fruit, but the abnormally developed cupules which can be found are spherical with free, linear, acute and pubescent scales (Figure 2).

Ecology: Occurs in the sandy soil of southwest Portugal, close to the coast in the Alentejo region. Populations can be found in cork oak (*Quercus suber*) dominated forests with sporadic pines such as *Pinus pinaster* Aiton and *P. pinea* L. The climate in this area is frost-free and characterized by high humidity and moderate rainfall.

Distribution: Endemic to Portugal, from south of Arrabida to Odemira in the Alentejo region.

The principal differences between this hybrid and its parents are shown in Table 2.

Table 2 Principal differences between *Quercus x celtica* and its parents - *Q. lusitanica* and *Q. suber*

Character	<i>Q. lusitanica</i>	<i>Q. x celtica</i>	<i>Q. suber</i>
Leaf morphology	Subelliptic	Lanceolate to oblong	Lanceolate
Leaf margin	Serrate	Serrate	Serrate
Marginal spines	Present	Present	Absent
Petiole length mm	1-4(-6)	2-8(-10)	(3-)6-15(-35)
Cupule scales	Ovate	Linear	Linear
- Pubescence	Dense	Dense	Sparse
- Position	Imbricate	Free	Free
- Apex	Obtuse	Acute	Acute
Foliar trichome types			
Simple-uniseriate	Present	Present	Absent
Bulbous	Present	Present	Absent
Solitary	Present	Present	Present
Fasciculate	Absent	Absent	Absent
Multiradiate	Present	Present	Absent
Stellate	Present	Present	Absent
Fused-stellate	Absent	Present	Present

Quercus x coutinhoi nothosubsp. *beturica* F.M. Vazquez, A. Coombes, M. Rodríguez-Coombes, S. Ramos & E. Doncel nothosubsp. nov.

= *Quercus faginea* subsp. *broteroi* (Coutinho) A. Camus x *Quercus robur* subsp. *extremadurensis* (O. Schwarz) A. Camus.

Latin Description:

Frutex cum folia coriacea; lamina (2,5-)3-8,5(-11,5) cm longa et (2-)3-6,5(-7,5) cm lata, supra et subtus glabra vel subtus glabrescens; ambitu oblongae vel aut spatulatae, apicem rotunda ex basi cordata aut inaequalia; sinuato-lobulata, lobis ovato-triangularibus, rotundis. Costae laterales utrimque 4-8(-10) angulo acuto, nervis sinuatis frequentibus in the lobis. Petiolus glabrous 0,6-1,2 (-2) cm longus. Plantae steribus, cum floribus solitaris et pedunculo pubescentis, 0,5-2,7 cm longus.

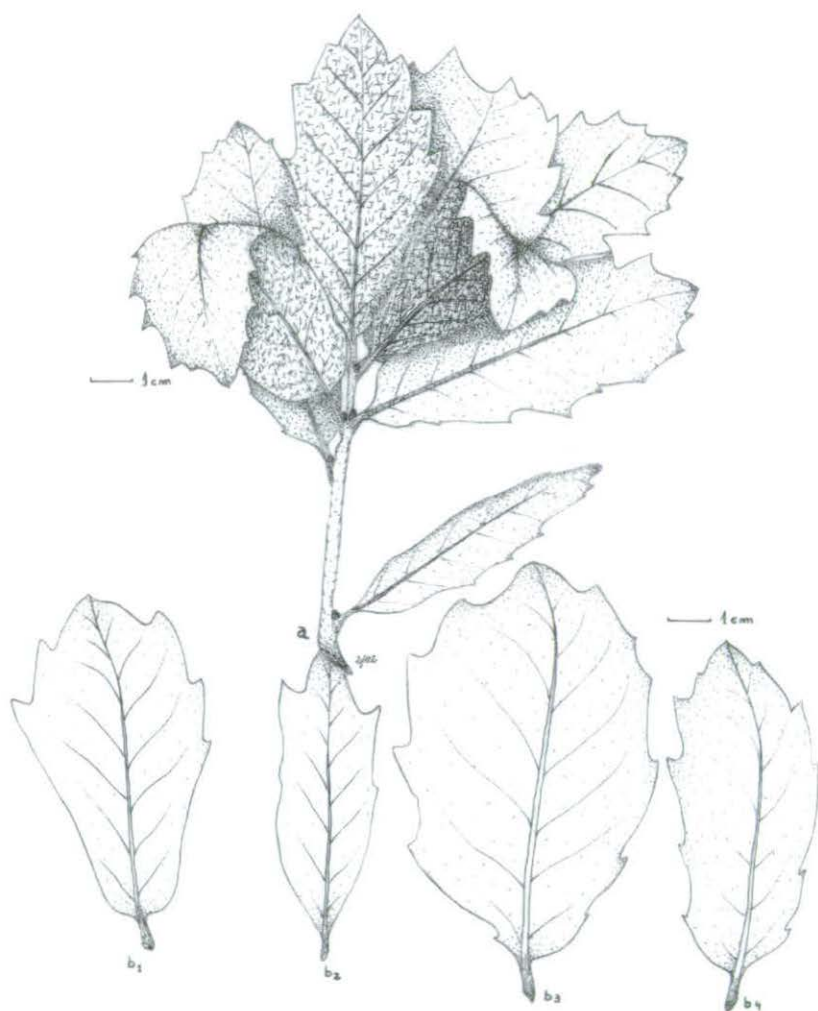


Figure 2. *Quercus x celtica* F.M. Vazquez, A. Coombes, M. Rodríguez-Coombes, S. Ramos & E. Doncel, from the type collection. a: small shoot, b1 to b4: leaf types,

Holotypus: HISPANIA: Extremadura, Badajoz, Valle de Santa Ana, 15-VIII-2002, M. Timacheff and F. M. Vázquez. HSIA.

Derivation: "Beturia" is the prehistoric name of the region where the new nothotaxon is found.

Description:

Shrub to 2 m-tall. Leaves coriaceous; lamina (3-)4-8(-9.5) -cm long and (2-)3-5.5(-7) -cm broad, adaxial surface tomentose, abaxial surface glabrous to subglabrate, lanceolate to oblong, margin serrate to sinuate-lobulate, with triangular lobes acute and obtusely mucronate at the apex, secondary veins sinuate; petiole pubescent, 0.2-0.8(-1) -cm long.

Plant sterile. Male inflorescence (catkins) up to 6-cm long, pubescent, the small flowers with ciliate scales. Female inflorescence (racemes) short, with 1 to 4 sterile flowers, the style long with a pubescent apex. Without fruit, but the abnormally developed cupules which can be found are spherical with free, linear, acute and pubescent scales (Figure 3).

Ecology: Occurs in the calcareous soil of southwest Spain, in thermic, frost-free areas with high annual precipitation (more than 700 mm/year). Populations can be found in cork oak (*Q. suber*) and *Q. rotundifolia* dominated forests with sporadic related oaks such as the *Q. faginea* group, *Q. canariensis*, *Q. robur subsp. estremadurensis* and *Q. coccifera*.

Distribution: Endemic to southern Spain, only known from the type locality in Santa Ana Valley, Badajoz Province.

The principal differences between this hybrid and its parents are shown in Table 3.

Table 3. Principal differences between *Quercus x coutinhoi* nothosubsp. *beturica* and its parents - *Q. faginea* subsp. *broteroi* and *Q. robur subsp. estremadurensis*.

Character	<i>Q. faginea</i> subsp. <i>broteroi</i>	<i>Q. x coutinhoi</i> nothosubsp. <i>beturica</i>	<i>Q. robur</i> subsp. <i>estremadurensis</i>
Leaf morphology	Oblong to oval	Oblong to subspatulate	Subspathulate
Leaf margin	crenate	crenate	lobed
Marginal spines	Absent or present	Absent	Absent
Petiole length mm	4-12(-22)	6-12(-20)	1-3
Cupule scales	Ovate	Lanceolate	Lanceolate
- Pubescence	Dense	Dense	Dense
- Position	Imbricate	Imbricate	Free
- Apex	Obtuse	Obtuse	Obtuse
Foliar trichome types			
Simple-uniseriate	Present	Present	Present
Bulbous	Present	Present	Absent
Solitary	Absent	Present	Present
Fasciculate	Present	Present	Present
Multiradiate	Present	Absent	Absent
Stellate	Present	Absent	Absent
Fused-stellate	Present	Absent	Absent

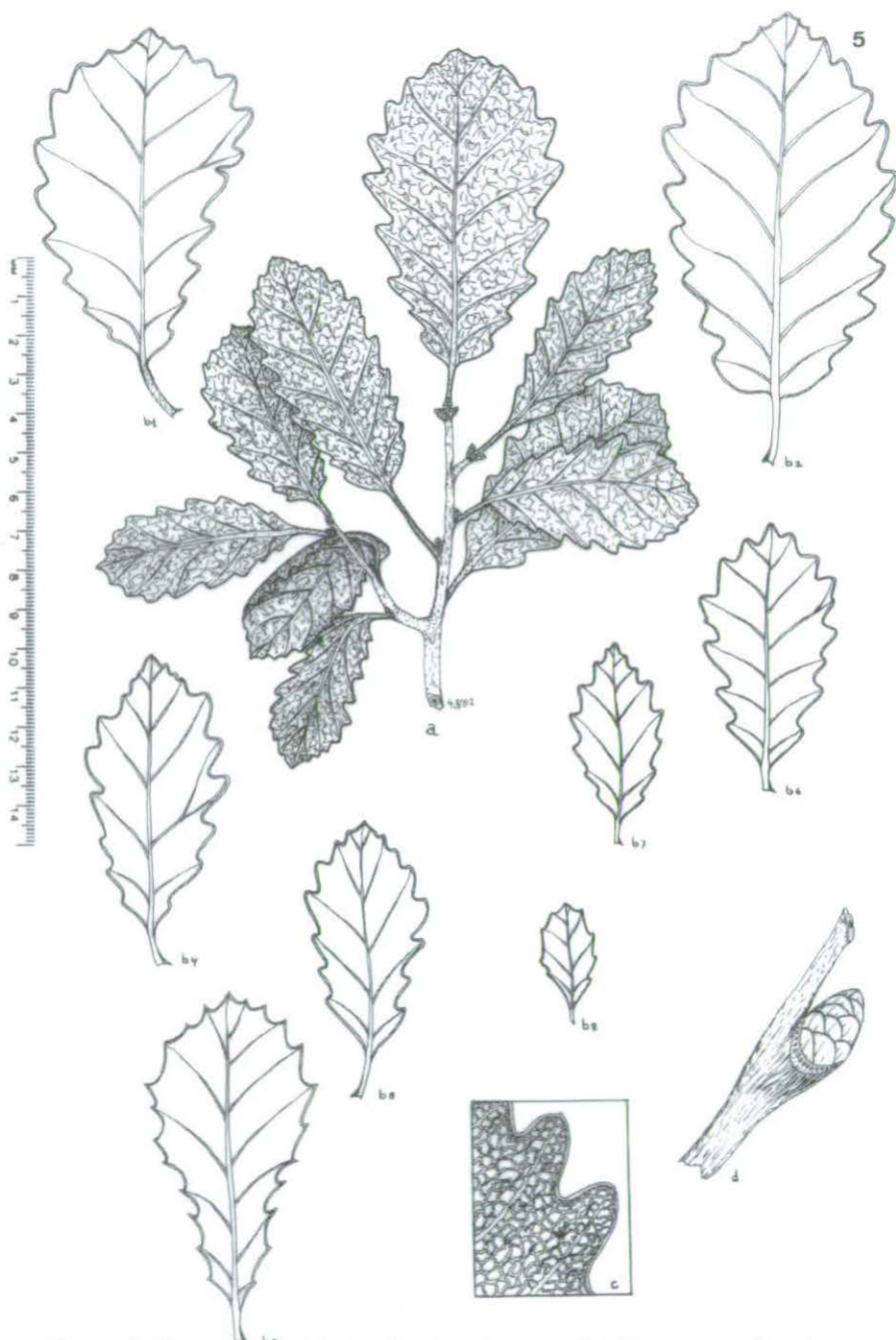


Figure 3. *Quercus* x *coutinhoi* nothosubsp. *beturica* F.M. Vazquez, A. Coombes, M. Rodríguez-Coombes, S. Ramos & E. Doncel, from the type collection. a: small shoot, b1 to b8: leaf types, c: abaxial surface. d: bud.

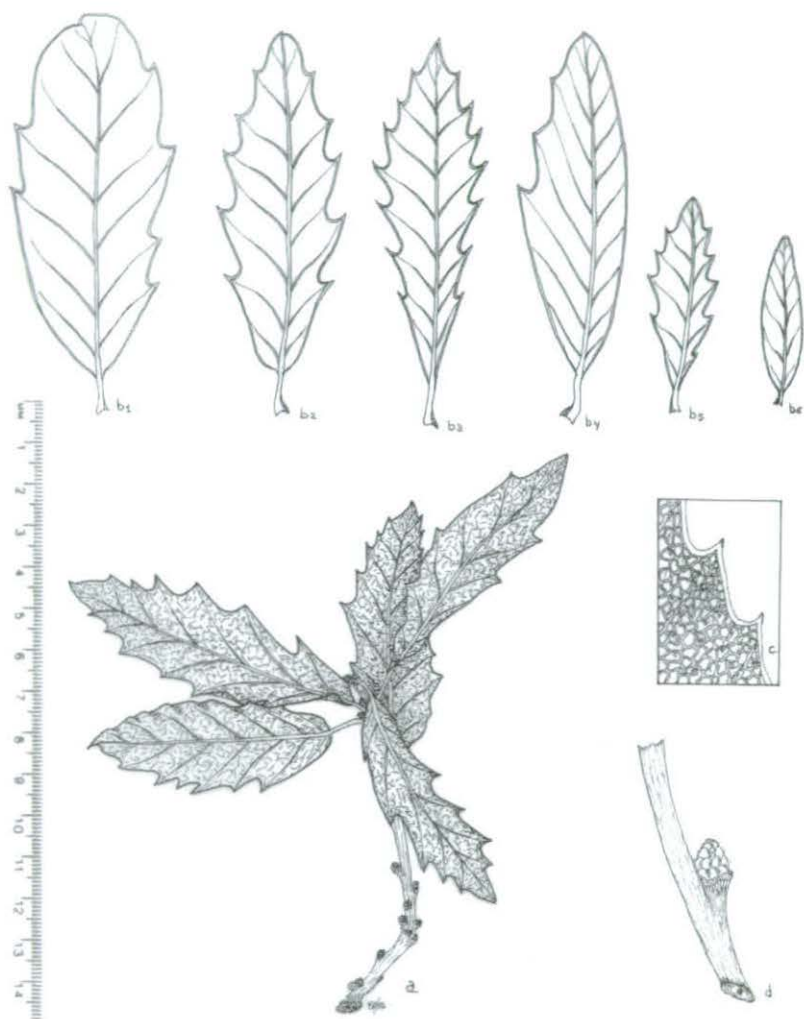


Figure 4. *Quercus x turneri* Willd., from Zumaia. a: small shoot, b1 to b4: leaf types, c: female flower. d: bud. e: abaxial surface.



Figure 5. *Quercus x turneri* Willd., from cultivation ("Pseudoturinei"). a: small shoot, b1 to b6: leaf types, c: abaxial surface. d: bud.

Another newly-discovered oak

The field work carried out by the authors during 2000 and 2001 added a great deal to the knowledge of oak hybrids in the Iberian Peninsula. In addition, the following is new to the flora of the Iberian Peninsula.

Quercus x turneri Willd.

= *Quercus ilex* x *Q. robur*

This is the first time this hybrid has been found, not only in the Iberian Peninsula, but anywhere in nature. It was collected by A. Coombes and M. Rodríguez-Coombes above the town of Zumaia, in Zarauz municipality, Guipuzcoa Province, in northern Spain, on a slope facing the Cantabrian Sea. A single tree was found growing between the parents in a hedgerow by the roadside. A voucher specimen is conserved in the Harold Hillier Herbarium at the Sir Harold Hillier Gardens. (A.J. Coombes, 591).

Quercus x turneri was originally described from a tree cultivated in Berlin but sent from the London nursery of Spencer Turner (Wiltshire & Coombes, 2001). The parentage has always been assumed to be *Q. ilex* x *Q. robur*, but this has never been proven.

We include illustrations of two plants assigned to *Q. x turneri*; one from northern Spain (natural population) and one from a plant cultivated at the Sir Harold Hillier Gardens. The commonly cultivated plant has been named 'Pseudoturneri,' (Figures 4 and 5).

Acknowledgements

We wish to acknowledge the corrections of the Latin descriptions by Ricardo Cabezas de Herrera.

References

- Amaral, J. 1990. *Quercus* L. In: S. Castroviejo, M. Lainz, G. López & al., *Flora Ibérica*, 2: 15-36.
- Battandier, J. A. & L. C. Trabut, 1890. *Flore de l'Algerie*. vol. 1. Argel.
- Benson, L. 1962. *Plant Taxonomy*. New York.
- Camus, A. 1936-39. *Chênes*. Paris.
- Carvalho, J. & J. Amaral, 1954. Carvalhos de Portugal. *Anais Inst. Sup. Agron.* (Lisboa) 21: 1-135.
- Cottam, W. P., J. M. Tucker & R. Drobnick 1959. Some clues to Great Basin postpluvial climates provided by oak distributions. *Ecology* 40: 361-377.
- Coutinho, A. X. 1888. Os *Quercus* de Portugal. *Bol. Soc. Broteriana* 6: 47-111.

- Hardin, J. W. 1979. Atlas of foliar surface features in woody plants I. Vestiture and trichome types of Eastern North American *Quercus*. *Bull. Torrey Bot. Club* 106(4): 313-325.
- Hardin, J. W. 1975. Hybridization and introgression in *Quercus alba*. *Journ. Arnold Arboretum* 56: 336-363
- Llamas, F., C. Pérez, C. Acedo & A. Peñas 1995. Foliar trichomes of the evergreen and semi-deciduous species of the genus *Quercus* (Fagaceae) in the Iberian Peninsula. *Bot. Jour. Linnean Society* 117(1): 47-57.
- Muller, C. H. 1951. The oaks of Texas. *Contrib. Texas Research Foundation* 1(3): 21-323.
- Muller, C. H. 1952. Ecological control of hybridisation in *Quercus*: a factor in the mechanism of evolution. *Evolution* 6: 147-161.
- Palmer, E. J. 1948. Hybrid oaks of North America. *Journ. Arnold Arboretum* 29: 1-49
- Rivas Martínez, S. & C. Saenz, 1991. Enumeración de los *Quercus* de la Península Ibérica. *Rivasgodaya* 6: 101-110.
- Stebbins, G. L. 1950. *Variation and Evolution in Plants*. New York.
- Thomson, P. M. & R.H. Mohlenbrock 1979. Foliar trichomes of *Quercus* subgenus *Quercus* in the Eastern United States. *Jour. Arnold Arboretum* 60(3): 350-366.
- Vázquez, F. M. 1995. Híbridos de *Quercus faginea* subsp. *broteroi* (Coutinho) A. Camus en el sudoeste de la Península Ibérica. *Anal. Jard. Bot. Madrid* 53(2): 247-251.
- Vázquez, F. M., S. Ramos & T. Ruiz 2000. Hybridisation processes in Mediterranean oaks from South Spain. *Jour. Intern. Oak Society* 12: 108-117
- Vicioso, C. 1950. El género *Quercus* en España. *Trab. Inst. Invest. y Exper. Forestales*. Madrid. 194 pp.
- Wilstshire, E. & A. J. Coombes 2001. *Quercus x turneri* Willd. – a rare London hybrid oak. *The London Naturalist*. 80: 21-27.

A REPORT ON THE OAKS OF BUCKINGHAM PALACE GARDEN

By Mark Lane

Head Gardener, Buckingham Palace, London SW1A 1AA

Situated in the very heart of London, the Buckingham Palace garden is a relatively quiet haven within a vibrant metropolis. The 16 hectares are home to an amazing diversity of flora and fauna that has built up over the past 175 years or so when the garden took on its present form. Native wild plants brush leaves with the truly exotic, providing a wealth of interest and great pleasure to the eye. It is a sheltered garden that, although receiving some frosts, is not as badly affected by them as Greater London and the surrounding counties. The 'London Effect' creates an environment that advances the season by about 3 weeks compared to the surrounding countryside, and raises average temperatures by 1.5 degrees centigrade.

Overall the soil in the garden is a free draining topsoil overlying heavy clay that seems to benefit the deeper rooting plants. The average rainfall is about 600 mm per year, but is supplemented with irrigation during dry spells. Many areas have been 'made up' with imported soils and in a number of cases, builder's rubble provides pH readings that range from 4 on the lawns to over 8 on the Mound.

William Townsend Aiton designed and created the present garden in or around 1825. He was The King's gardener and was in charge of the gardens at a number of other Royal residences including Kew Gardens and Kensington Palace. W.T. Aiton was a latecomer in the field of design, but he was much influenced by his greater predecessors, William Kent (d.1748) and Lancelot Brown (d.1783). He successfully concealed the stark boundaries of the garden and certainly some of the fine trees to be found in the garden today are Aiton's planting. The construction work was carried on in to King William IV's reign, and Aiton was still working on it when Queen Victoria came to the Throne in 1837. In the case of many London Parks, early to mid-nineteenth century plantings initially thrived, but were later impacted by air pollution, as the Industrial Revolution, combined with coal fires, created adverse atmospheric conditions. This left only the toughest of trees and shrubs and replanting had to be carried out regularly. The garden relied for a great proportion of its cover until the late 1970s on the English elm (*Ulmus procera*), but the population of this noble tree, like in so many other parts of the British Isles was devastated by Dutch Elm Disease. In the years up to 1980 the garden lost about 100 specimens, some of them quite magnificent and there were only two English elms remaining in 1979.

In many London parks, squares and large gardens the dominant tree is the London plane (*Platanus x hispanica*) and it is no different here. Nearly 100 mature or nearly mature specimens create a heavy canopy of shade for the lower plantings. Occasional other species are evident; common ash (*Fraxinus excelsior*), horse chestnut (*Aesculus hippocastanum*), common beech (*Fagus sylvatica*) and Indian chestnut (*Aesculus indica*), but there are surprisingly few old oaks. There are four Turkey oaks (*Quercus cerris*) that appear quite old, with the best of these near the Waterfall and along Constitution Hill. Unfortunately, there are no planting records before the mid 1950s so it is only possible to guess their age. Using Alan Mitchell's guide of an increase in girth of approximately 1" per year, I estimate the trees to be approximately 100 years old.

Since Queen Victoria's time, there has been a custom of planting trees in the garden to commemorate special occasions. The Prince of Wales, The Princes Royal, The Duke of York and The Earl of Wessex have planted four pedunculate oak (*Q. robur*) specimens from acorns raised in the year of their birth. These trees have taken their place amid other commemorative trees of various species. A hybrid oak (*Q. x libanerris* 'Rotterdam') was presented by the Council of the International Dendrology Society after their visit on 23 October 1987 and planted by Queen Elizabeth II on 11 November 1989. This tree had reached 7.1 m in 1998.

Tom Deighton, the Head Gardener from 1984 to 1990 planted, amongst many other trees, a selection of oaks that included the pin oak (*Q. palustris*) and red oak (*Q. rubra*), both of which provide a variable autumn colour display depending on the season. *Q. serrata* forms part of the dense screening along Grosvenor Place.

The first oak planted when I became Head Gardener in 1992 was the black jack oak (*Q. marilandica*). It was a poor specimen when it arrived, but perseverance has paid off to the point where it has now become well established attaining a height of 4m in 2001, with a crown spread of 2.5 m. This planting was soon followed by a California black oak (*Q. kelloggii*), given to the garden by the late John Bond, former Keeper at the Savill Gardens, Windsor. What wonderful autumn colour, the most vivid red, on a tree that is now 4.5m tall. Next followed a small specimen of the daimio oak (*Q. dentata*), with its large downy leaves that stay on all through the



Quercus marilandica, Black Jack Oak
Photo courtesy of Kevin Ward



Quercus dentata
Photo courtesy of Kevin Ward

winter. This tree was slow to establish but had achieved 4m by 2001. A small hybrid of the deer oak (*Q. sadleriana*) with English oak (*Q. robur*), given to the garden by Bill George of the Sir Harold Hillier Gardens is planted on the front edge of the Main Lawn near the lake. Both *Q. shumardii* and *Q. aliena* are planted above the Tennis Court and will, in time, replace two large and over-mature cherries growing nearby.

The evergreen oaks will soon play an important part in the winter landscape of the garden. These include a

Californian live oak or encina (*Q. agrifolia*) with its spiny leaves, which although only planted in 1994 was 5.5 m tall by 2001. Others include *Q. coccifera*, *Q. ilex* 'Fastigiata', *Q. x hispanica*, bamboo-leaved oak (*Q. myrsinifolia*), *Q. phillyreoides* with wonderful bronze coloured new foliage in the spring, and *Q. wislizeni*.

The swamp white oak (*Quercus bicolor*) is planted close to the Ice Well in the Mound. That there is a fine old specimen of this uncommon species in nearby Kensington Gardens measuring 22 m in height, with a girth of 249 cm, shows that it can flourish in Central London.

The garden to date contains about sixty seven different, established oak species, while many more are in pots, growing until large enough to plant out (see Table 1).

Recent developments to the collection have involved researching and obtaining smaller growing oaks, that will be less than 5 m in height when mature. These will provide an interesting under-storey for present plantings whilst again giving a reasonable indication of growth habit in Central London.

It is also important to place the collection in context with those of other Central London green spaces. As already mentioned Kensington Gardens have a good specimen of *Quercus bicolor* and in addition to that, four (two old and two young) *Quercus x hispanica* 'Lucombeana' trees, one young *Quercus frainetto*, two young and two mature *Quercus palustris* trees, an old *Quercus petraea* and two young *Quercus phellos*.

Hyde Park has a young *Quercus acutissima*, a young *Quercus aliena*, two young *Quercus coccinea* 'Splendens', four *Quercus x hispanica* 'Lucombeana's' of various forms, one *Quercus frainetto*, 25 mostly young *Quercus palustris* trees (with

one old specimen near the New Lodge), six young *Quercus phellos* and a *Quercus suber*. There is also a very rare survivor of Turner's original hybrid between *Quercus ilex* and *Quercus robur*, given the new cultivar name of *Quercus x turneri* 'Spencer Turner'.

The Chelsea Physic Garden has three *Q. coccifera*'s with one of those having achieved about 6 m on a good trunk, four *Q. ilex* trees, with two taller than 13 m, and a *Q. macrolepis* planted as a memorial tree by



Quercus agrifolia

Photo courtesy of Kevin Ward

the previous curator, Sue Minter. There is also a young *Q. myrsinifolia*, and a *Q. salicina* donated by Kew Gardens. Finally there is an old specimen of *Q. suber*, mentioned by Webster in 1920.

Conclusion

It might be considered that our reliance on the London plane is too high and that is one justification for planting a wider selection of species. London no longer suffers from the dreadful 'smogs' that once plagued both its inhabitants and its plant life. Other species now have a fighting chance and oaks must play a part in the future canopy of the garden for generations to come. Growing them successfully here may inspire their wider use throughout London's streets and green spaces. In years to come we hope to amass a fine and renowned collection, which should be a joy to anyone with an interest in oaks.

Table 1. *Quercus* in Buckingham Palace Garden

<i>Q. acerifolia</i> *	<i>Q. garryana</i> *	<i>Q. pacifica</i> ptd 2001
<i>Q. acutifolia</i> *	<i>Q. georgiana</i> hybrid ptd 2002	<i>Q. pagoda</i> ptd. 1998
<i>Q. acutissima</i>	<i>Q. glauca</i> *	<i>Q. palustris</i> ptd 1984, 1985, 1988 & 1990
<i>Q. acutissima</i> subsp. <i>chenii</i> ptd. 1993	<i>Q. gravesii</i> *	<i>Q. petraea</i> ptd. 1991
<i>Q. affinis</i> ptd 2003	<i>Q. grisea</i> ptd 2002	<i>Q. phillyreoides</i> ptd. 1991
<i>Q. agrifolia</i> ptd. 1994	<i>Q. hartwissiana</i> ptd. 2001	<i>Q. prinus</i> hybrid ptd. 1998
<i>Q. alba</i> ptd. 1998	<i>Q. x hastingsii</i> ptd 2002	<i>Q. prinoides</i> *
<i>Q. aliena</i> ptd 1994	<i>Q. x heterophylla</i> *	<i>Q. polymorpha</i> ptd 2002
<i>Q. aliena</i> var. <i>acutiserrata</i> ptd. 1995	<i>Q. x hickelii</i> *	<i>Q. 'Pondaim'</i> ptd 1998
<i>Q. alnifolia</i> ptd 2001	<i>Q. hypoleucooides</i> ptd 2003	<i>Q. prinoides</i> ptd 2002
<i>Q. x andegavensis</i> *	<i>Q. ilex</i>	<i>Q. pubescens</i> ptd. 1999
<i>Q. arkansana</i> ptd 2001	<i>Q. ilex</i> 'Fastigiata'	<i>Q. pungens</i> ptd 2001
<i>Q. austrina</i> ptd. 1998	<i>Q. ilicifolia</i> *	<i>Q. pyrenaica</i> ptd. 1998
<i>Q. x bebbiana</i> *	<i>Q. imbricaria</i> ptd. 1997	<i>Q. robur</i> ptd 1954, 1969, 1981, 1985 & 1987
<i>Q. berberidifolia</i> ptd. 2001	<i>Q. infectoria</i> ptd. 1997	<i>Q. robur</i> f. <i>fastigiata</i> ptd. 1996 & 2000
<i>Q. bicolor</i> ptd. 1999	<i>Q. kelloggii</i> ptd. 1994	<i>Q. robur</i> subsp. <i>imeritina</i> *
<i>Q. buckleyi</i> *	<i>Q. x kewensis</i> *	<i>Q. rubra</i> ptd 1991
<i>Q. x bushii</i> ptd 2002	<i>Q. laceyi</i> *	<i>Q. rugosa</i> ptd 2001
<i>Q. calliprinos</i> ptd 2002	<i>Q. laevis</i> *	<i>Q. x runcinata</i> *
<i>Q. canariensis</i> *	<i>Q. laurifolia</i> ptd. 1994	<i>Q. rhyssophylla</i> *
<i>Q. canbyi</i> *	<i>Q. leucotrichophora</i> ptd 2001	<i>Q. rhyssophylla</i> hybrid ptd. 1995
<i>Q. cerris</i>	<i>Q. x libanerris</i> 'Rotterdam' ptd. 1989	<i>Q. sadleriana</i> hybrid ptd 1997
<i>Q. chapmanii</i> ptd 2001	<i>Q. libani</i> ptd 2002	<i>Q. sartorii</i> *
<i>Q. chrysolepis</i> ptd. 1999	<i>Q. x ludoviciana</i> ptd. 1995	<i>Q. x saulii</i> ptd 2002
<i>Q. coccifera</i> ptd. 2000	<i>Q. lusitanica</i> *	<i>Q. schottkyana</i> ptd 2002
<i>Q. coccinea</i>	<i>Q. lyrata</i> *	<i>Q. schuettei</i> ptd 2000
<i>Q. conspersa</i> ptd. 2000	<i>Q. macranthera</i> *	<i>Q. shumardii</i> ptd 1994
<i>Q. crassifolia</i> ptd. 2001	<i>Q. macrocarpa</i> *	<i>Q. serrata</i> ptd. 1985 & 1995
<i>Q. crassipes</i> ptd 2002	<i>Q. macrolepis</i> ptd. 2001	<i>Q. stellata</i> *
<i>Q. x hispanica</i> 'Lucombeana' ptd. 1991	<i>Q. margaretae</i> *	<i>Q. suber</i> *
<i>Q. cuspidata</i> *	<i>Q. mexicana</i> ptd 2000	<i>Q. texana</i> ptd 1998 & 2002
<i>Q. dalechampii</i> *	<i>Q. michauxii</i> *	<i>Q. trojana</i> subsp. <i>trojana</i> ptd 2002
<i>Q. dentata</i> ptd. 1994	<i>Q. mongolica</i> subsp. <i>crispula</i> var. <i>grossesserata</i> *	<i>Q. turbinella</i> ptd 2002
	<i>Q. montana</i> *	<i>Q. undulata</i> *
<i>Q. dumosa</i> ptd 2002	<i>Q. muhlenbergii</i> ptd 2002	<i>Q. vaccinifolia</i> ptd 2001
<i>Q. durata</i> ptd. 2001 & 2002	<i>Q. myrsinifolia</i> ptd. 1997 & 1998	<i>Q. velutina</i> ptd 2002
<i>Q. ellipsoidalis</i> ptd. 2000	<i>Q. myrtifolia</i> ptd 2002	<i>Q. velutina</i> 'Rubrifolia' ptd. 1995
<i>Q. emoryi</i> *	<i>Q. nigra</i> ptd. 1993	<i>Q. virginiana</i> ptd 1994
<i>Q. engelmannii</i> ptd 2003	<i>Q. oblongifolia</i> *	<i>Q. x warei</i> *
<i>Q. fabri</i> ptd 2002	<i>Q. obtusata</i> *	<i>Q. wislizeni</i> ptd 1999
<i>Q. x fernaldii</i> *	<i>Q. oglethorpensis</i> *	<i>Q. wislizeni</i> var. <i>frutescens</i> *
<i>Q. gambelii</i> *	<i>Q. oxyodon</i> ptd 2002	

* growing in containers in the propagation area awaiting planting

Table 2. Oaks at Kensington Palace

<i>Q. arizonica</i> ptd 2003	<i>Q. ilex</i> ptd.1902
<i>Q. dentata</i> 'Pinnatifida' ptd 2002	<i>Q. kelloggii</i> ptd. 2000
<i>Q. douglasii</i> ptd. 2000	<i>Q. libani</i> ptd 2002
<i>Q. fabri</i> ptd 2002	<i>Q. x saulii</i> ptd 2002
<i>Q. faginea</i> ptd. 2000	<i>Q. schottkyana</i> ptd 2003
<i>Q. hemisphaerica</i> ptd 2003	<i>Q. texana</i> ptd 2002

Table 3. Oaks at Marlborough House

<i>Q. hartwissiana</i> hybrid ptd 2001	<i>Q. lobata</i> ptd 2000
<i>Q. x hispanica</i> 'Lucombeana'	<i>Q. robur</i> f. <i>pyramidalis</i> ptd 2001

PROGRESS IN NORTHERN RED OAK GENOMICS IN THE SOUTHERN APPALACHIANS

Matthews, S.A.^a Trout, B.K.^a Schlarbaum, S.E.^b Bonds, W.D.^a

^a Department of Chemistry and Physics, Western Carolina University,
Cullowhee, NC 28723

^b Department of Forestry, The University of Tennessee, Knoxville, TN 37901

Abstract

While published material regarding molecular biology of the genus *Quercus* is limited, considerable progress has been made recently in understanding the genetic basis of growth and development in model plant systems such as hybrid poplar and *Arabidopsis thaliana* (Chaffey, 2002). Techniques of comparative genomics are currently being used to analyze the northern red oak (NRO, *Quercus rubra*) genome using information derived from these smaller genomes. NRO was selected as a species for study here in the southern Appalachians for several reasons. Economically it is the most valuable hardwood in the region and the tree faces serious challenges to continued natural regeneration. Furthermore, an NRO seedling orchard is available within the area. In this article we will discuss techniques and strategies currently being used to isolate and sequence NRO genetic material; the inherent difficulties in conducting this type of research on forest trees; the results collected to date; and how these results will be used to further the biological knowledge of this majestic tree.

Introduction

The northern red oak is an ecologically and economically desirable hardwood species common in the southern Appalachian Mountains. Over 20,000,000 cubic feet of northern red oak is harvested annually in North Carolina at an annual value of over \$30,000,000 US (FIA, 2003). The tree's ecological value is evidenced by large mast production, with good acorn crops yielding over 250,000 acorns per acre. Up to 40% of the mast is consumed by wildlife which become important vectors for the distribution of NRO acorns. In this region, NRO prefers moist, north facing slopes at altitudes up to 1,680 meters. Its wood is widely used for lumber and veneer (Hicks 1998). However, tree growth is limited by long periods of juvenility; acorn production in the third decade; limited competitive natural regeneration; infestation by such pests as red oak borer, canker worm, and gypsy moth; and fungal diseases such as oak wilt and shoestring fungus (Hicks, 1998).

The cellular, molecular, and developmental processes mediating wood formation in *Quercus* is poorly understood at best. There is only limited data concerning the influence of molecular mechanisms on differentiation in the secondary vascular system and the relationships between genetic variability and wood quality. Most molecular research on the family *Fagaceae* and the genus *Quercus* has been for the purpose of establishing phylogenetic relationships and not such practical targets as wood production. As of April, 2003, there were only nine genes from NRO listed in the GenBank nucleotide database (NCBI, 2003) while there are an estimated 20,000 genes present in angiosperms (Bradshaw, 2002). We have worked toward isolating NRO messenger RNAs (mRNAs) for the purpose of rapidly and inexpensively identifying gene coding sequences. The challenge lies not only in being able to isolate

and identify the genes, but in interpreting this information within the context of the cell and the tree as a living organism (i.e., functional genomics). While the exact size of the NRO genome (see note below) is not known, calculations based on 0.9 pg of DNA per cell suggest a nuclear complement of approximately 800 million base-pairs of genomic DNA (Barreneche et al. 1998). The time and cost involved in the complete DNA sequencing of such a large genome (genomic library), coupled with the fact that protein coding regions probably comprise only 1-3% of this total, greatly influenced our project plan.

The construction of a complimentary DNA (cDNA) library allows the investigator to disregard the large majority of an organism's genome and focus solely on those regions that are transcribed into mRNA and ultimately protein. The construction of such a library begins with the tissue of interest and ends numerous steps later with a complimentary DNA representation of the mRNAs initially present. Segments of the DNA can then be sequenced and comparisons made to sequences in public databases. The construction of cDNA libraries from as many NRO tissues as possible, including shoot meristems, roots, leaves, acorns, pollen, developing bark, embryos and vascular cambium, will increase the complexity of the libraries and the number of unique or novel genes discovered.

Note: An organism's entire complement of nuclear DNA is known as its genome. In every living cell, segments of nuclear DNA are transcribed into lengths of mRNA which in turn are translated into proteins that perform the biochemical activities of the organism. The more frequently a gene is expressed, the greater the levels of mRNA exported from the cells' nucleus to the ribosomes for translation. Gene expression varies with cell type but can also be affected by exposure to external stimuli such as temperature, photoperiod, nutrient and water availability, and disease.

NRO Seed Orchard and Sample Collection

Samples were recovered from the Watauga Northern Red Oak Seedling Seed Orchard near Butler, Tennessee which was created from an open-pollinated progeny test established in 1973 by the Tennessee Valley Authority (TVA). One-year old (1-0) seedlings, grown at the TVA Nursery near Clinton, Tennessee, were used for the plantation. The seedling seed orchard was created in 1987 by thinning the smallest trees in each four-tree plot, leaving one or two trees (Lafarge and Lewis, 1987). Approximately 1150 trees were left in the plantation after thinning. The majority of families were retained (ca. 200), as nothing was known at the time about fruiting and management of NRO seed orchards. Another thinning occurred following the 1994 growing season, leaving approximately 750 trees (Schlarbaum *et al.*, 1998).

Working towards the objective of discovering genes in the wood forming region, tissues from the cambial zone were harvested by removing the outer bark with a hammer and chisel, visually identifying the boundary between bark and sapwood and then scraping the exposed surfaces of the sapwood with a chisel to a depth of 0-2mm. The tissue is collected in foil paper and snap frozen in liquid nitrogen.

Experimental: RNA Isolation

There are numerous methods for isolating RNA from plants. The chemical composition of the individual plant tissue is an important factor in selecting an extraction process. Initial stages of the project were difficult due to the lack of published material concerning isolation of genetic material from forest trees. Five different RNA isolation techniques were evaluated before selecting a method developed by Chang (1993). This method uses a cationic detergent and was selected because of

the ability to process large quantities of starting material and its ability to neutralize interfering compounds.

Samples are processed in the lab by grinding to a fine powder in a mortar and pestle under liquid nitrogen. A cationic detergent (CTAB) is used as the lysis buffer, followed by three chloroform extractions to remove polysaccharides and proteins. Centrifugation at 10,000 x the force of gravity expedites the organic and aqueous phase separation. The aqueous layer is removed leaving the unwanted proteins and polysaccharides in the organic phase. The RNA is precipitated out of the aqueous solution with LiCl and dissolved in an appropriate amount of water (Chang 1993). Once RNA has been isolated, the sample is separated on an agarose/formaldehyde denaturing gel to ensure quality and quantified using an UV spectrophotometer (260 nm) (Sambrook et al. 1989). Quality is assessed by the presence of distinct ribosomal bands in the gel. To establish a high quality cDNA library the RNA isolated from a source should be intact with as many full-length mRNAs as possible. The occurrence of two distinct ribosomal bands with a color intensity of the larger fragment twice as intense as the smaller fragment suggests the presence of intact, undegraded RNA. The ribosomal bands from the 28S and 18S subunits from NRO tissue can be clearly seen in Figure 1. Lane 1 contains a RNA marker used to estimate the size of unknown fragments.

The amount of RNA recovered from an individual sample depends on various things including the quality and tissue type of the starting material. Average RNA yields from leaves- 23 ug/g, root radicals- 40 ug/g, stem shoots- 38 ug/g, dormant cambial zone- 3 ug/g, and early spring cambial tissue- 11 ug/g have been obtained thus far.

Once an adequate amount of high quality total RNA from a specific tissue is obtained mRNA can then be isolated. Affinity chromatography is designed to manipulate a unique structural characteristic of mRNA. Full length mRNA messages have a poly-A tail composed of up to 250 adenosine residues (Brown 2002). Utilizing the affinity of the adenosine residues in the mRNA tail for complementary thymine residues on the chromatography column, the mRNA is isolated from the total RNA. 790ug of total RNA has been demonstrated to yield 10ug of NRO mRNA.

Tree cells also contain large quantities of RNA degrading enzymes known as RNases. These enzymes are present as part of the innate immune system to protect the tree from viruses that are in the form of RNA. RNases are also released from the vacuoles of cells to degrade genetic messages that are no longer needed. To overcome the problems of RNase contamination the work area must be kept painfully clean and all solutions are treated to remove RNase activity. Tissue samples must be stored frozen at -80°C to reduce the activity of RNases.

Conclusions

Messenger RNA is now being synthesized into complementary DNA utilizing Superscript II® reverse transcriptase (Invitrogen). The double stranded cDNA will then be ligated into a virus that infects a strain of the *E. coli* bacteria. The bacteria will produce millions of clones for each ligated message, creating a library of genetic messages unique to tissues of NRO. Clones will be randomly picked and regions of ligated DNA are excised and subjected to automated sequencing. After numerous clones are sequenced the quality of the sequence will be evaluated and compared to model organisms. Since the cDNA library is the end product of many individual steps its efficiency can be compromised by inefficiency at any step.

The preparation of full-length cDNA libraries is advantageous in that most clones will then contain the complete coding sequence, which accelerates sequencing, biocomputation, and protein expression (Carninci *et al.* 2000). The normalization of these libraries further enhances the quality and complexity. The mRNA content of a cell varies depending on expression. Some mRNAs are abundant in a cell with 5-10 species comprising at least 20% of the mass, while 500-2000 intermediately expressed species comprise 40%-60%. There can be as many 10,000-20,000 rare messages in a cell that account for less than 20%-40% of the mRNA mass (Carninci *et al.* 2000). Reddy *et al.* separately constructed standard and normalized cDNA libraries of rice for comparison. A redundancy of about 10% was reported for the first 200 clones of the non-normalized library, compared with 3.5% in the normalized library. The discovery of novel genes also increased with the normalized library compared to the non-normalized, being 28.2% and 5% respectively (Reddy *et al.* 2002).

Along with sequencing randomly chosen cDNAs, microarray technology offers the potential for the rapid identification of a large number of genes (DeRisi, Vishwanath, and Brown, 1997). Utilizing a microarray chip, fluorescently tagged cDNA's can be hybridized against single stranded DNA segments from thousands of known genes attached to a chip. Chips are presently available for *A. thaliana*, an angiosperm whose entire genome has been sequenced, and *Populus* chips have been spotted with more than 13,000 EST's, but are not as accessible as those for *A. thaliana* (Wullschlegel *et al.* 2002). Those genes that have been conserved in NRO would hybridize with those on the microarray chip, and a scanner can then identify the degree of hybridization at each individual spot, allowing those genes that are present in the cDNA to be ascertained.

Knowledge of the transcriptional messages controlling reproductive development, wood formation and defense mechanisms will be essential for the effective integration of biotechnology into tree improvement work (Pena & Sequin 2001). The public database that will emerge from this project will facilitate the discovery of novel genes in northern red oak. By applying the described molecular techniques we hope to further the biological understanding of the northern red oak tree.

Work Cited

- Barreneche, T., Bodenes, C., Lexer, C., Trontin, J., Fluch, S., Streiff, R., Plomion, C., Kremer, A. (1998) A genetic linkage map of *Quercus robur* L. based on RAPD, SACR, microsatellite, minisatellite, isozyme and 5S rDNA markers. *Theoretical Applied Genetics* 97:1090.
- Bradshaw, T. (2002). Geneticists branch out to sequence poplar genome. *Nature* 415:725.
- Brown, T.A. (2002). *Genomes*. New York: John Wiley & Sons, 286.
- Carninci, P., Shibato, Y., Norihito, H., Sugahara, Y., Shibato, K., Masayoshi, I., Hideaki, K., Okazaki, Y., Masami, M., and Hayashizaki, Y. 2000. Normalization and subtraction of cap-trapper-selected cDNAs to prepare full-length cDNA libraries for rapid discovery of new genes. *Genome Research* 10: 1617-1630.

- Chaffey, N. 2002. Why is there so little research into the cell biology of the secondary vascular system of trees? *New Phytologist* 153:213-223.
- Chang, S., Puryear, J., and Cairney, J. 1993. A simple and efficient method for isolating RNA from pine trees. *Plant Molecular Biology Reporter*. 11: 113-116.
- DeRisi, J.L., Vishwanath R.I., Brown P.O. 1997. Exploring the Metabolic and Genetic Control of Gene Expression on a Genomic Scale. *Science* 278:680-685.
- Hicks, R. Jr. (1998). Ecology and Management of Central Hardwood Forests. New York: John Wiley & Sons, 174-176.
- LaFarge, T. and Lewis R.A. 1987. Phenotypic selection effective in a northern red oak seedlings seed orchard. In *Proceedings of the Southern Forest Tree Improvement Conference*, 16-19 June 1987, College Station, Texas. 200-207.
- Merkle, S.A., Dean J.D. (2000). Forest Tree Biotechnology, *Current Opinion in Biotechnology* 11:298-302.
- National Center for Biotechnology. Online: <http://www.ncbi.nlm.nih.gov/2003>
- Pena, L., Seguin A., (2001). Recent Advances in the Genetic Transformation of Trees. *Trends in Biotechnology* 19:500-506.
- Plomion C., Leprovost G., Stokes A. (2001) Wood Formation in Trees. *Plant Physiology* 127:1513
- Reddy, A., Ramakrishna, W., Sekhar, C., Nagabhushana, I., Babu, P., Bonaldo, M.F., Soares, M.B., and Bennetzen, J. 2002. Novel genes are enriched in normalized cDNA libraries from drought-stressed seedlings of rice. *Genome*. 45: 204-211.
- Sambrook, J., Fritsch, E.F., and Maniatis, T. 1989. *Molecular Cloning: A Laboratory Manual*. Cold Spring Harbor Press, Cold Spring Harbor, New York.
- Schlarbaum, S.E., Barber, L.R., Cox, R.A., Cecich, R.A., Grant J.F., Kormanik Paul P., LaFarge, T., Lambdin P.L., Lay S.A., Post, L.S., Proffitt, C.K., Remaley, M.A., Stringer, J.W., and Tibbs, T. 1998. Research and development activities in a northern red oak seedling seed orchard. In *Diversity and adaptation in oak species*. Proc. 2nd IUFRO Genetics of *Quercus* meeting, K. Steiner, ed. 185-192.
- United States Forest Service. Forest Inventory and Analysis Timber Product Output Database Retrieval System 1997. Online: <http://srsfia.usfs.msstate.edu/rpa/tpo/>
- Wullschlegar, S., Jansson, S., and Taylor, G. 2002. Genomics and Forest Biology. *The Plant Cell* 14: 2651-2655.

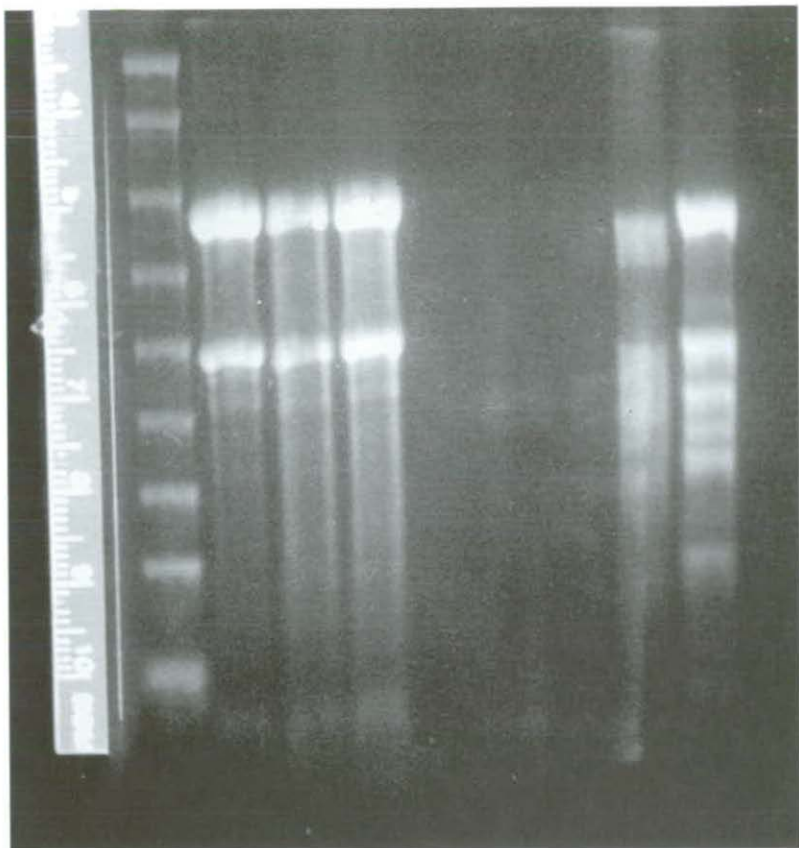


Figure 1. Formaldehyde/denaturing gel of RNA samples from stem shoots (lane 2) and root radicals (lane 3 & 4). Lane 1 contains an RNA marker used for size identification. (Sigma-Aldrich Company, St. Louis, Mo.)

Authors' Guidelines

General Policies

The International Oak Society will accept articles for *International Oaks* from members or non-members as long as the material presented is pertinent to the genus *Quercus*. Written contributions may be scientific/technical papers, historical, horticultural, instructional or general interest material (stories/articles of a particular tree, event, place, person, etc.) or letters to the editor; a mix of categories is encouraged. Material may be previously published or unpublished. The author's name, title, address, telephone and/or (fax) number, and e-mail (if available) should be included. Any contributions longer than 7500 words must be approved in advance by the editor.

Copyrights

International Oaks is not copyrighted, but authors, photographers and artists may claim copyrights on their work. Anyone wishing to use portions of *International Oaks* for other publications should secure permission from the author, photographer or artist, and include a credit line indicating *International Oaks* as the source of the material. All contributors submitting work thereby release their contribution for publication under the terms stated herein. Authors take full and sole responsibility for securing releases for use of material obtained from other sources, and agree to indemnify the International Oak Society against any claim of plagiarism involving their contribution.

Format

Contributions will be accepted in any legible format, in English only. Text should be restricted to a single, standard font, preferably Times or Times New Roman. No more than two levels of subheadings should be included. Electronic files written in WordPerfect or Microsoft Word are preferred and must be accompanied by a paper copy. Text may be submitted via e-mail (ddmccreary@ucdavis.edu) or on a floppy disk. Do not add page numbers, borders, headers or footers. Single space between sentences, and avoid bold type, custom margins, and other optional format codes. Authors submitting papers in other formats must pay US \$10 per manuscript page, in advance, to help defray the additional costs of reformatting for publication.

Illustrations and photographs can be submitted in a high resolution format as jpegs if digital art is sent. Do not place art in the body of the work. Drawings, slides or photos may be mailed to be scanned; the art work will be returned upon request. Illustrations and photos should be sharp and compatible with monochromatic reproduction.

Style, citation methods, and abstracts are left to the reasonable discretion of the author. Refer to the current Council of Biological Editors (CBS) style Manual for Biological Journals for general guidelines. Tables and charts which are not submitted in camera-ready form (or in an electronic format approved in advance by the editor) may be rejected, or subjected to a minimum \$30 (US) production fee. *Do Not* place tables or charts within text files. All measurements should be expressed in metric units, or in metric followed (in parenthesis) by English. Scientific names, with authority or with reference to the treatment in a specified standard taxonomic manual, must be included for each taxon discussed if there is any possibility for confusion.

Review

The editorial committee and editor reserve the right to edit all contributions for grammar, correct English translation, current nomenclature, generally accepted taxonomic concepts, scientific accuracy, appropriateness, length and clarity; but assume no responsibility to do so. If such review results in significant disputes of factual material, the author will be contacted if possible, or the paper may be rejected. Every effort will be made to retain the original intent of the author.

International Oaks—

The Journal of the International Oak Society
c/o Doug McCreary-Integrated Hardwood Range Mgt. Program
University of California



01 EP 0000696261

MID:TR8 DT: 03/01/2003 ShelfID:B4762
Name: International Oaks
Rec: 01/29/2010 Abxcnt: 13 BookRev: 0
DateTxt: Spring2003 Priority:
FTFile:
Source: Vendor: Multi CkInit: JCO
TOC: ININE A&I: ININE Special: N/A
TOCsrc:H Scan: BOS Ship:Y Hold:N
FT: N/A Authabx: Y AbxTyp:
PDF: BOS Imtype: CDOC: N
MDScan:N EmbDue: Rights: N



I N T E R N A T I O N A L O A K S