THE
Journal
JANUARY / FEBRUARY 2014 | ISSUE 1 VOL. 28
OF THE AMERICAN CHESTNUT FOUNDATION

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Mighty Giants: An American Chestnut Anthology

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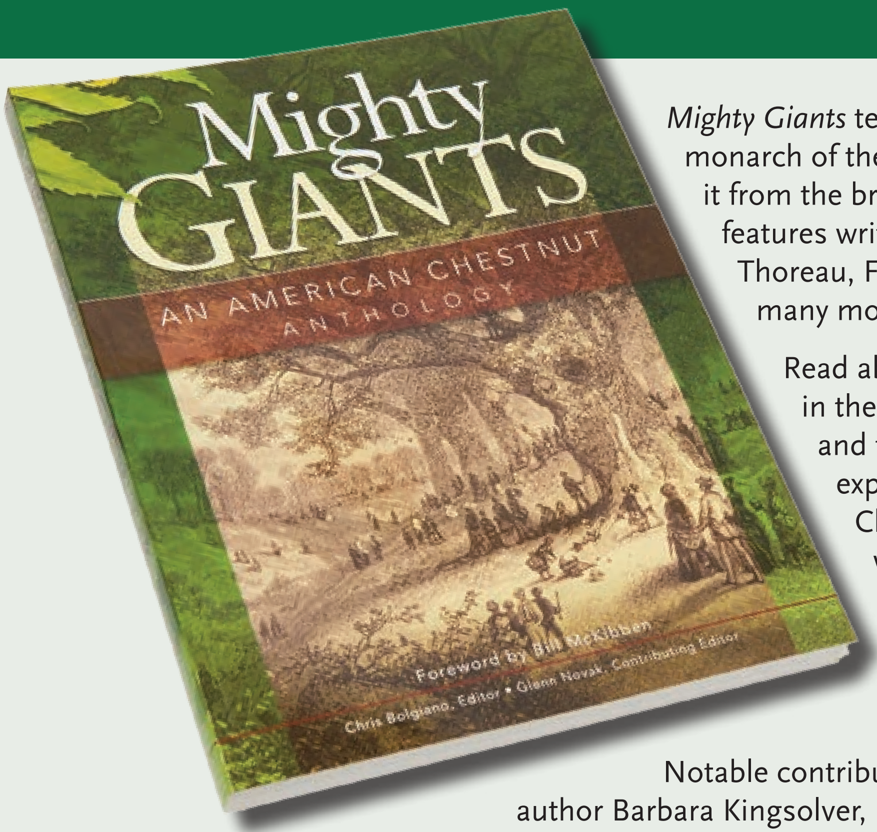

Mighty Giants tells the inspiring story of the once mighty monarch of the eastern forests and the struggle to save it from the brink of extinction. This full-color anthology features writings and artwork by Jefferson, Lincoln, Carter, Thoreau, Frost, Winslow Homer, Andrew Wyeth, and many more.

Read about the chestnut's importance to early settlers in the eastern wilderness and its value to wildlife and the ecosystem. Learn about the fearless plant explorer who tracked down the blight in war-torn China, and the plant pathologists and geneticists who labored long and valiantly to understand the blight and find a way to thwart it. It is a story of hope, of small but vital triumphs, as the secrets of the American chestnut and its deadly nemesis are gradually revealed.

Notable contributors include former President Jimmy Carter, author Barbara Kingsolver, Nobel Peace Prize laureate Norman Borlaug, and Bill McKibben, author of *The End of Nature*. Full Color, 296 pages.

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The Mission of The American Chestnut Foundation

Restore the American chestnut tree to our eastern woodlands to benefit our environment, our wildlife, and our society.

We harvested our first potentially blight-resistant nuts suitable for widespread testing in 2005, and the Foundation is beginning reforestation trials with potentially blight-resistant American-type trees. The return of the American chestnut to its former range in the Appalachian hardwood forest ecosystem is a major restoration project that requires a multi-faceted effort involving 6,000 members and volunteers, research, sustained funding, and most important, a sense of the past and a hope for the future.

About Our Cover Image

A Common Redpoll perches on a chestnut limb during a chilly day in Rimersburg, PA. Common Redpolls can survive temperatures of -65°F, so this winter hasn't proven to be much of a challenge. Photo by Mark Moore.

THE Journal OF THE AMERICAN CHESTNUT FOUNDATION

INSIDE THIS ISSUE

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Snow-covered burs on a chestnut tree at Meadowview Research Farms.
Photo by David Bevins

Grey squirrel eating a chestnut in Rimersburg, PA.
Photo by Mark Moore

It's More Than Just The American Chestnut

By Bryan Burhans, President & CEO

There's no doubt a laser-like focus is needed to successfully complete any task. And there's no doubt TACF has kept our focus on developing a chestnut tree suitable for reintroduction into our eastern woodlands. However, our success will deliver far more benefits than just bringing back one tree from almost definite extinction.

As we look into our crystal ball we can only imagine the magnitude of the issues that will face our forests in the foreseeable future. History has demonstrated the damaging ramifications of introduced alien pathogens; the chestnut blight is just one example. If you think of these threats with respect to the probability of their introduction, the future of our forests is in jeopardy. When the chestnut blight accidentally found its way into our ports of entry, global trade was far less than it is today. And you can now jump on an airliner and reach another continent within a few hours, which makes the potential transport of pathogens fast and easy.

Knowing that the introduction of new pests and pathogens is an absolute, it is critical that we invest in and develop new technologies to improve our effectiveness in dealing with them. TACF is doing this now, and the model we have developed provides a template to help conservationists methodically tackle these issues.

Our forests face other challenges as well. Fragmentation of forest ownership is one such challenge. The decrease in the size of individual forest tracts creates a barrier for landowners to actively manage their forests. Invasive species, growing deer populations, climate change, and eroding timber markets all threaten our ability to manage our forests for wildlife and timber products, and to protect our water and air. Our forests provide so many benefits that we typically take for granted. Although we have plenty of trees, and in fact we have more timber today than we did prior to WWII, the function and health of these forests will continue to erode if we don't take action today.

Reintroducing the American chestnut will help us deal with future issues that will face our forests while offering us an effective tool to deal with some current issues. For example, regenerating young forests, which grow fast and sequester large amounts of carbon, provides a real tool for dealing with climate change. Throughout the eastern United States, young forests, often referred to as early successional habitat, are crucial for many species of wildlife to survive, yet very few of these habitats currently exist. Regenerating forests to include reintroduction of the American chestnut allows managers the means to deal with other issues that face our forests at the local level, such as eradicating non-native invasive species, improving timber stand diversity, and enhancing wildlife habitat.

Fortunately, TACF can do more than just talk about saving our forests; we have the opportunity to do something about it.

2014 Annual Meeting Location and Dates Announced!

TACF's 2014 Annual Meeting will take place at the Northern Virginia 4-H Educational Conference Center, in Front Royal, Virginia. Photo courtesy of Northern Virginia 4-H Educational Center

Mark your calendars for TACF's 2014 Annual Meeting: October 18, 2014, at the Northern Virginia 4-H Educational Center in Front Royal, Virginia. TACF Board will meet on October 16-17. The Center is situated on 229 acres of land nestled in the Blue Ridge Mountains, only minutes away from historic Front Royal and 70 miles from Washington, DC. It sits at the gateway to Shenandoah National Park in Warren County, which is rich with Civil War history, busy with community celebrations, and full of small-town camaraderie. As details about the meeting come together, we will keep you informed through notices in *The Journal*. For more information about the venue, visit www.nova4h.com/conferencing/.

More Than Sixty-five TACF Volunteers Participate in Trees Database Trainings

Attendees at the New England Regional Meeting all participated in a Trees Database training session on December 7, 2013. Photo courtesy of Kendra Gurney

TACF regional scientists have trained more than 65 orchard managers and active volunteers to input data into the Trees Database, a new online tool that tracks the development and release of TACF's blight-resistant American chestnuts.

Until recently, TACF did not have an efficient tool to capture the tremendous amount of information we collect to further the restoration of the American chestnut tree. TACF's breeding program reaches across a large geographic network of growers and partners necessitating the management of large amounts of data. Upon completion, the database will allow information, such as planting locations, observations, pedigree analyses, and wild tree locations, to be accessible by varied users including TACF staff, university researchers, and citizen scientists.

"Trees Database trainings are our first attempt at opening up the database to our membership," said Sara Fitzsimmons, TACF Regional Science Coordinator Supervisor. "Our goal is to help orchard managers and Chapter volunteers to record things like wild American chestnuts, pollination activities, planted trees, and more. We would like to see TACF volunteers recording all chestnut breeding and planting activities in the online database by this spring."

Though it is functional for the majority of our data storage needs, the Trees Database is only 25% complete and some features can be clunky and difficult to use. Upcoming phases of development will focus on improving data integrity and the overall user experience, ensuring that our staff and members will input data correctly and easily. Development is ongoing but can be hastened with increases in funding. If you would like to contribute time or financial support, contact Sara Fitzsimmons at sara@acf.org or call 814-863-7192.

Frontier Culture Museum 2014 Winter Lecture Series to Feature the American Chestnut

The Frontier Culture Museum of Virginia is a living history museum located in the heart of the Shenandoah Valley in Staunton, Virginia. It tells the story of the people who migrated from the Old World to America and the life they created in the Shenandoah Valley. Their frontier life and culture cannot be fully conveyed without including the powerful influence of the American chestnut trees that towered over the mountain landscape of the east for centuries as the dominant hardwood species. The wood was used for everything from furniture to fence rails, and the nuts fed mountain people and their livestock, as well as an array of native wildlife.

The theme of the museum's 2014 Winter Lecture Series is "The American Chestnut in the Forests of the Frontier." This series will raise public awareness of the importance of the American chestnut tree to frontier culture when it was thriving, and the efforts now under way to restore it to its natural habitat.

"The Frontier Culture Museum and the American Frontier Culture Foundation are pleased to dedicate the 2014 Winter Lecture Series to the American chestnut Tree," said Justin Reiter, Director of Marketing for the museum. "We have wanted the American chestnut tree to be a topic for some time. We are excited to welcome members of TACF to Staunton and the museum."

The Frontier Culture Museum has put together an outstanding lineup of speakers for their Winter Lecture Series. All lectures will take place in the Dairy Barn Lecture Hall and are free to the public. Doors open at 6:30 pm and all lectures begin at 7:00 pm.

Tuesday February 18, 2014

Donald Davis – "Giving Character to the Landscape: Finding Chestnuts in American Frontier History"

Tuesday February 25, 2014

John Scrivani – "How Chestnut Acquired and Lost Keystone Species Status"

Tuesday March 4, 2014

Harmony J. Dalgleish – "The Ecology of American Chestnut Restoration"

Tuesday March 11, 2014

Ralph Lutts – "Chestnut Trade on the Blue Ridge of Southwest Virginia"

The museum has also assembled a special lodging package for $99.00 that includes a one-night stay at the Stonewall Jackson Hotel (single room for two people), VIP Lecture Series Seating (for two), two one-time general admission tickets to the museum (good for one year), and complimentary breakfast at the hotel with the guest speaker the morning following the lecture.

Generous support for the lecture series comes from Stonewall Jackson Hotel and Conference Center, ArborLife, Blue Ridge Lumber, The American Chestnut Foundation, and the Virginia Chapter of The American Chestnut Foundation. For more information, contact justin.reiter@frontiermuseum.org or call (540) 332-7850.

An American chestnut tree in Tualatin, Oregon. With i-Tree software, the ecosystem benefits of an open-grown shade tree like this one can be calculated. Photo by Doug Gillis

The Benefits of Trees in Our Communities

By Matt Brinckman, Mid-Atlantic Regional Science Coordinator

Whether in a forest or in a front yard, trees provide us with benefits that are often overlooked: they create shade, stabilize soils, pull carbon from the atmosphere, help to slow and filter storm water runoff, and provide wildlife habitat. Trees also are aesthetically pleasing, mark the start and end of our seasons, and reduce noise pollution. The presence of trees has been shown to expedite recovery time for patients recuperating from various medical treatments, and reduced crime rates have been correlated with increased tree and shrub cover in urban communities.

As our urban landscape continues to grow and change, many have attempted to start placing values on some of the services that trees so quietly provide us. The US Forest Service has developed i-Tree, a software program to use as a tool for urban forestry analysis and benefits assessment. i-Tree not only has the capability to allow for analysis of plot or census data for any piece of land from a single tree to an entire urban forest, it also can model ecosystem benefits derived from the trees represented in the sample.

The table shows the annual ecosystem benefits provided by a single American chestnut of a given diameter derived from an online calculator that uses i-Tree software and data. Obviously, many assumptions go into the model, including those made about the tree's characteristics based on species data, but also assumptions involving energy use, property values, and climatic data, based on the location that is put into the model.

Diameter (in)	2	3	4	5	6	8	10	12
Overall Benefits ($)	6	15	24	33	44	65	84	101
Storm water (gallons)	82	157	232	381	604	1,050	1,619	2,312
Property Value ($)	4	10	17	24	30	42	51	57
Energy (kWh)	5	11	16	24	35	55	77	101
CO_2 (lbs)	23	52	81	116	157	238	313	383

Annual ecosystem benefits of American chestnut trees of various diameters calculated using the National Tree Benefit Calculator with a Charlottesville, VA, zip code.

To calculate these values for your own yard, visit www.treebenefits.com/calculator. It is also possible to enter entire orchard inventories to derive an orchard-level benefit evaluation using the freely available i-Tree software. To download i-Tree, register for an account at www.itreetools.org.

Dr. William Powell Named Forest Biotechnologist of the Year

Dr. William Powell is the fifth scientist to be named Forest Biotechnologist of the Year. Photo courtesy of SUNY-ESF

Dr. William A. Powell, professor at the State University of New York, College of Environmental Science and Forestry (SUNY-ESF), director of the Council on Biotechnology in Forestry, and TACF Science Cabinet member, has been named 2013 Forest Biotechnologist of the Year by the Institute of Forest Biotechnology (IFB).

Powell is the fifth scientist to win this award and was nominated because of his pioneering work, leadership, and outreach using biotechnology to restore the American chestnut.

Lori Knowles, chair of the board of IFB, said, "Bill's willingness to communicate about his work, engage with the public, and collaborate with colleagues from other disciplines is both commendable and visionary. Bill embodies the principles of science, dialogue and stewardship on which the IFB is built, and thus he is an ideal recipient of this year's Forest Biotechnologist of the Year award."

For more than 20 years, Powell has worked to develop an American chestnut tree that resists disease, using modern biotechnology techniques to add just two to four genes to enhance blight resistance, so the tree will retain all the traits of a typical American chestnut tree but also be able to survive chestnut blight. He and his colleagues have planted more than 500 transgenic American chestnut trees at 10 locations in the U.S., including the New York Botanical Garden in the Bronx.

In Memory of and In Honor of Our TACF Members November-December 2013

In Memory of

Virgil R. Beary
Oliver and Eileen Evans

Andrea Clarke
Craig Metz

Richard Coker
Constance Cremese
D. Boyd and Stacey Johnson
Sydna Johnson
Tom and Beth Johnson
William Johnson
Scott and Vikki Shirley

Jay Frank Davidson
Ronald Chamberlin
Nancy Rife

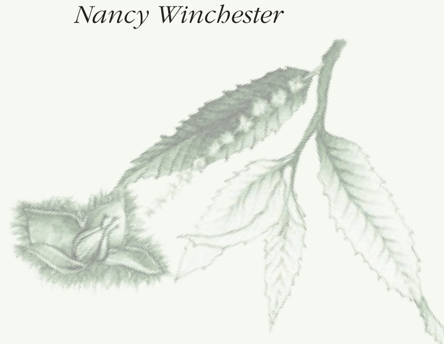
Wylie Pierson Johnson
Monica Smigliani

James McCallister
Kimberly Stevens

William Silber
Joseph and Joanne Moore

In Honor of

Adele Cerrelli
Nancy Winchester



(above) Lois Melican beside chestnut trees at Moore State Park orchard, which she and Denis manage for the MA/RI Chapter. Photo by Yvonne Federowicz

Denis Melican (on the right) and other Chapter volunteers prepare to inoculate trees at the MA/RI Chapter' Tower Hill orchard in Boylston, MA. Photo by Kendra Gurney

Denis and Lois Melican

Truth be told, there aren't many spousal teams in the ranks of American chestnut enthusiasts. Typically, it's either one or the other spouse who devotes a portion of his or her time to restoration efforts. Denis and Lois Melican are the exception to this rule and work as a powerful team dedicated to the return of the American chestnut.

The Melicans live in Spencer, MA. Lois works for the Massachusetts State Park system and Denis recently retired from his position as a park supervisor. In the fall of 2002, while conducting a walking tour of Moore State Park in central Massachusetts, someone on the walk asked if they were familiar with TACF. After the tour they researched the Foundation and decided to join. Since then, both have made huge contributions to the development and restoration efforts of the MA/RI Chapter. In the spring of 2003, the Melicans planted the first American chestnut research orchard on state land in Massachusetts at Moore State Park. Keeping in mind the aesthetics of the beautiful historic landscape, the Melicans used the natural contours of the site to determine the best orientation for planting the orchard's rows. Visitors are able to follow the orchard's growth as the seasons and years pass, since it is situated in a small field adjacent to the parking lot. Early on, the Melicans kindled a partnership that gives local scouts the opportunity to explore citizen science while helping with the care of the orchard.

Currently, both Denis and Lois serve on the MA/RI Chapter Board and Lois is the Chapter Vice President. They are also active in the TACF Education Committee, and are helping to develop a series of presentations for volunteers to use for outreach events.

"Lois and Denis regularly conduct chestnut presentations and other educational events across our region and have made invaluable contacts for the Chapter," says MA/RI Chapter President Yvonne Federowicz. "Their cheerful, reliable, and willing attitudes help make our meetings and events a pleasure for all."

Outside of their work for TACF, Lois loves cooking with chestnuts and appreciates the nutritional value that they give to any dish. She says that chestnuts, whether the flour or nuts, can be incorporated into many dishes. For chapter meetings, presentations, and events Lois usually bakes a chestnut treat to share. She's even been known to make "chestnut twinkies"! The Melicans enjoy hiking, taking trips into Boston, and recently have traveled to Ireland. They make a point to attend TACF's Annual Meeting every year and treasure interacting with other members during that time.

Genetic Diversity of American Chestnut Is Highest in the Southern US:

The Evidence from Nuclear and Chloroplast DNA Studies

Dr. Fenny Dane[1] and Dr. Paul H. Sisco[2]

[1] Department of Horticulture, Auburn University, Alabama 36849

[2] The American Chestnut Foundation, Asheville, North Carolina 28801

Background

American chestnut (*Castanea dentata*) is a wild, outcrossing species with tiny, wind-borne pollen. Before the advent of the chestnut blight the species occupied a nearly continuous range from Maine to Alabama, and overall it has been described as a single metapopulation* (Kubisiak and Roberds 2006). Nevertheless, the ice sheets that have periodically covered large parts of North America in the last two million years had a clear and measurable effect on genetic diversity in the species. During each glacial period, the temperate forest of the East retreated to the southern coastal plains. Analysis of preserved pollen suggests that *Castanea* migrated very slowly northward following the most recent glacial retreat, and that while oak-chestnut forests dominated central Appalachia more than 5000 years ago, the chestnut arrived in Connecticut only 2000 years ago (Davis 1983).

Nuclear DNA, contained in chromosomes, travels in pollen as well as seed. Thus nuclear DNA can spread over long distances, and the idea of a 'metapopulation' refers only to this nuclear component of the genome*. There are two other components of the genome in plants, however: mitochondrial* DNA (mtDNA) and chloroplast* DNA (cpDNA). Evidence to date indicates that in *Castanea* species, such as American chestnut, cpDNA is strictly maternally inherited (Sisco et al. 2014). Thus cpDNA can only travel via seed, a much slower and more geographically restricted movement than travel via pollen. Variations in cpDNA are sometimes found in distinct geographically delineated sub-populations, even when the overall range of a species like American chestnut is nearly continuous (Shaw and Small 2005). This paper reviews what is known about the present genetic structure and genetic diversity of American chestnut.

Definition of "American chestnut"

Figure 1. American chestnut (A) vs. Allegheny (B) and Ozark (C) chinkapin burs and nuts. Photos by (A) Joe Schibig, (B) Paul Sisco, and (C) Shawn Smith

What is an "American chestnut?" In the central and southern part of its range, where chestnuts and chinkapins are often found together, this can be a difficult question to answer. Multiple fruits per bur (usually three) are characteristic of American chestnut, distinguishing it from the chinkapins with one fruit per bur (Johnson 1988). Chestnut burs also have two sutures at right angles and open into four parts, whereas chinkapin burs have a single suture and open into two parts (Figure 1). The types and location of hairs also vary between species (Johnson 1988). Some American chestnut populations in the South have leaves that are intermediate between "standard chestnut" and "standard chinkapin" in appearance, making it difficult to assign the plants to one species or the other (Shaw et al. 2012; Li and Dane 2013). In this paper we focus exclusively on those plants that were clearly "American chestnut" by analysis of leaf and bur characteristics.

Highest level of nuclear DNA variation in American chestnut populations is found in the South

To investigate the genetic variation in the nucleus of American chestnut, both enzyme and DNA markers have been used. Enzymes are encoded by DNA, so differences in enzyme sequence reflect differences in DNA sequence. Huang et al. (1998), using analysis of variation in enzymes and DNA in 12 populations (16 – 30 trees per population) found that chestnut in North America showed lower levels of genetic diversity than chestnut species in Asia and Europe with one exception: the southernmost American chestnut population, located in central Alabama, contained a relatively high level of diversity. In recent studies, Kubisiak and Roberds (2003, 2006) extracted nuclear DNA from more than 1158 trees from 22 sample sites throughout the Appalachian

Definition of Terms (denoted within the article with *)

Metapopulation: A metapopulation consists of a group of spatially separated populations of the same species that interact at some level. In the case of chestnut, this interaction between subpopulations most often happens by wind-borne pollen, which can be carried long distances by air currents.

Genome: The genome is the total complement of genes in an individual organism. Plants have three genomes. Most genes reside on chromosomes in the nucleus. This is the **nuclear genome**. A much smaller number of genes reside on circular DNA structures in the mitochondria (**mitochondrial genome**) and in the chloroplasts (**chloroplast genome**).

Mitochondrion: The mitochondrion (plural mitochondria) is a small bacteria-like structure in the cells of plants and animals that provides energy. It is the "powerhouse" of the cell. Each mitochondrion contains a small number of genes. Proteins encoded by genes in the mitochondrion interact with proteins encoded by genes in the nucleus. In most species, mitochondria are inherited only from the mother. Thus when crosses are made between different species, such as between American and Asian chestnut trees, the F_1 hybrid contains the nucleus with chromosomes of both species and the mitochondrion of the mother tree. These two genomes, nuclear and mitochondrial, are not used to "working together" when they are from different species, and this may result in abnormalities such as pollen sterility in the F_1 plant.

Chloroplast: The chloroplast is a small bacteria-like structure in the cells of plants that captures the energy of light and converts it into stored energy. This capturing of light energy emitted by the sun is critical for life as we know it. Each chloroplast contains genes, and proteins encoded by the chloroplast interact with proteins encoded by nuclear genes. In many plants such as chestnut trees, chloroplasts are inherited only from the mother. As in the case of mitochondria, F_1 hybrid chestnut trees contain the chloroplasts of one species and the nucleus with chromosomes of both species. Most often this does not cause any noticeable effect on the F_1.

Haplotypes: In chestnut, the nucleus contains two copies of 12 chromosomes, one from the male parent and one from the female parent. The nuclear genotype of an individual plant reflects this dual contribution from both parents and is called "diploid" from the Greek word for double. An individual gene can be in two forms (alleles), one coming from the male parent and one from the female parent. In contrast, the mitochondria and chloroplasts contain only one copy of their circular genome, a copy they inherited exclusively from their female parent. The genotype of this single copy is called a "haplotype" from the Greek word meaning single.

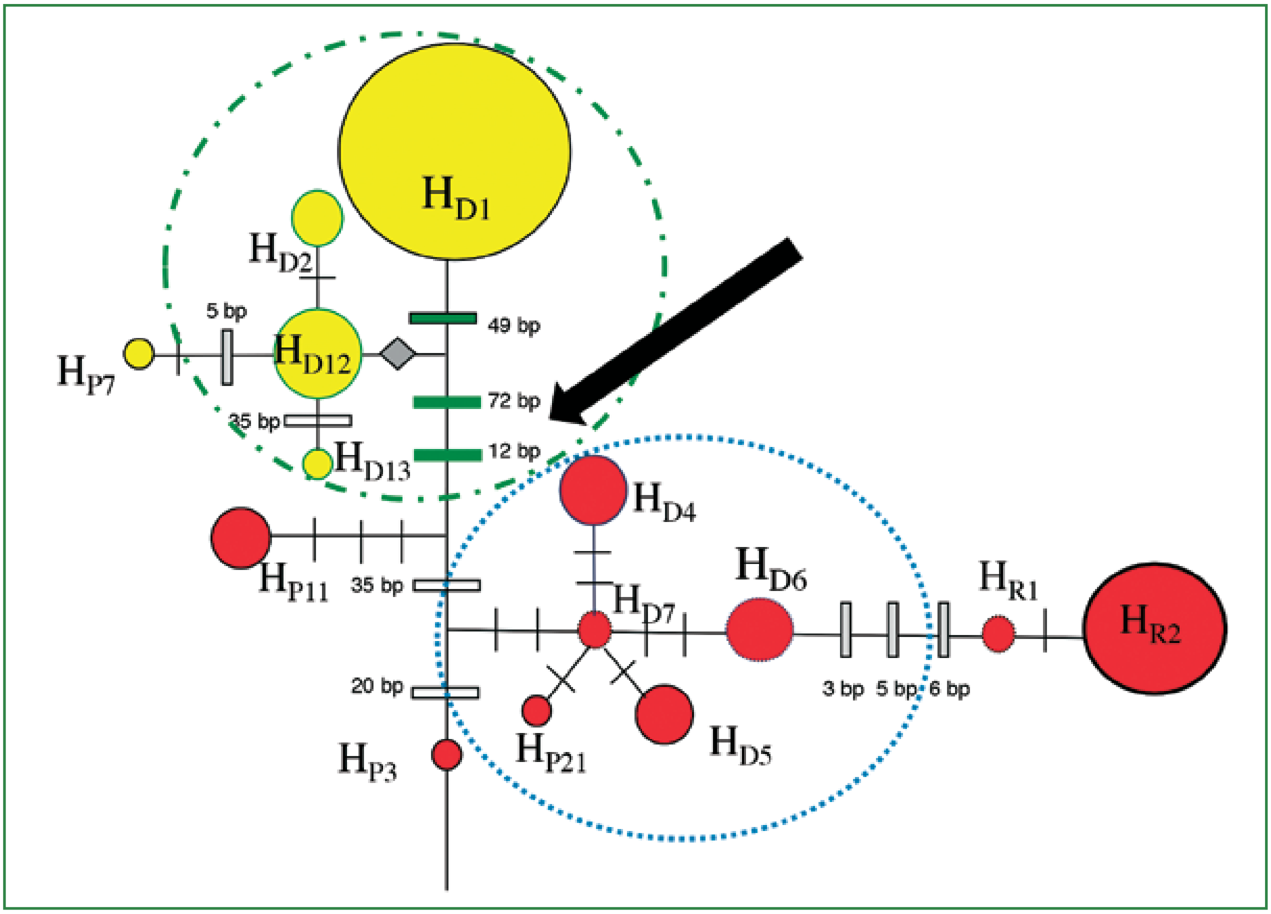


Figure 2. Variation in chloroplast haplotypes among American chestnut and Allegheny chinkapins based on work in the Dane Laboratory (Li and Dane 2013). Each circle represents a unique haplotype. Boxes represent DNA insertions or deletions and lines represent single base-pair changes in the chloroplast DNA sequence. The large arrow points to the two deletions that were used by Kubisiak and Roberds (2003, 2006) in their attempt to identify American chestnut by chloroplast haplotype. Haplotypes above the arrow, located within the green dotted circle, and represented by yellow dots in Figure 3, have the deletions. Haplotypes below the arrow, located within the blue dotted circle, and represented by red dots in Figure 3, do not have the deletions. The samples were collected from the following: **American chestnut trees**: D1 – the most common American chestnut chloroplast haplotype found in trees from Maine to Alabama; D2 – Lacon, in Morgan County, AL; D4 – Laurel and Whitney Counties, KY; D5 and D7 – Coweeta Lab, Macon County, NC; D6 – Lula Lake, Lookout Mountain, GA; D12, D13, R1, and R2 – Ruffner Mountain, AL. **Allegheny chinkapin trees**: P3 – Eglin Air Force Base, FL; P7 – Rabun County, GA; P11 – Iron Mountain, VA; P21 – Varnamtown, NC.

Mountain range. Based on analysis of 6 highly variable nuclear DNA markers, they concluded that 95% of the genetic variation was found *within* each of the 22 sites. But the highest level of genetic diversity and the greatest number of rare variants in DNA sequence in American chestnut were in the southern part of its range.

Unusual chloroplast DNA types are more common in the South

Variants in chloroplast genomes are called haplotypes*. Chloroplast haplotypes can be confined to a single species of plants or they can be shared among species, as found in North American *Prunus* (Shaw and Small 2005).

When Kubisiak and Roberds (2003, 2006) were soliciting American chestnut samples for their study, they were concerned that some leaves of other chestnut or chinkapin species might be collected by mistake. In hopes that a particular chloroplast haplotype might distinguish American chestnut from the other species, they sequenced parts of the chloroplast genome from several different *Castanea* species from North America,

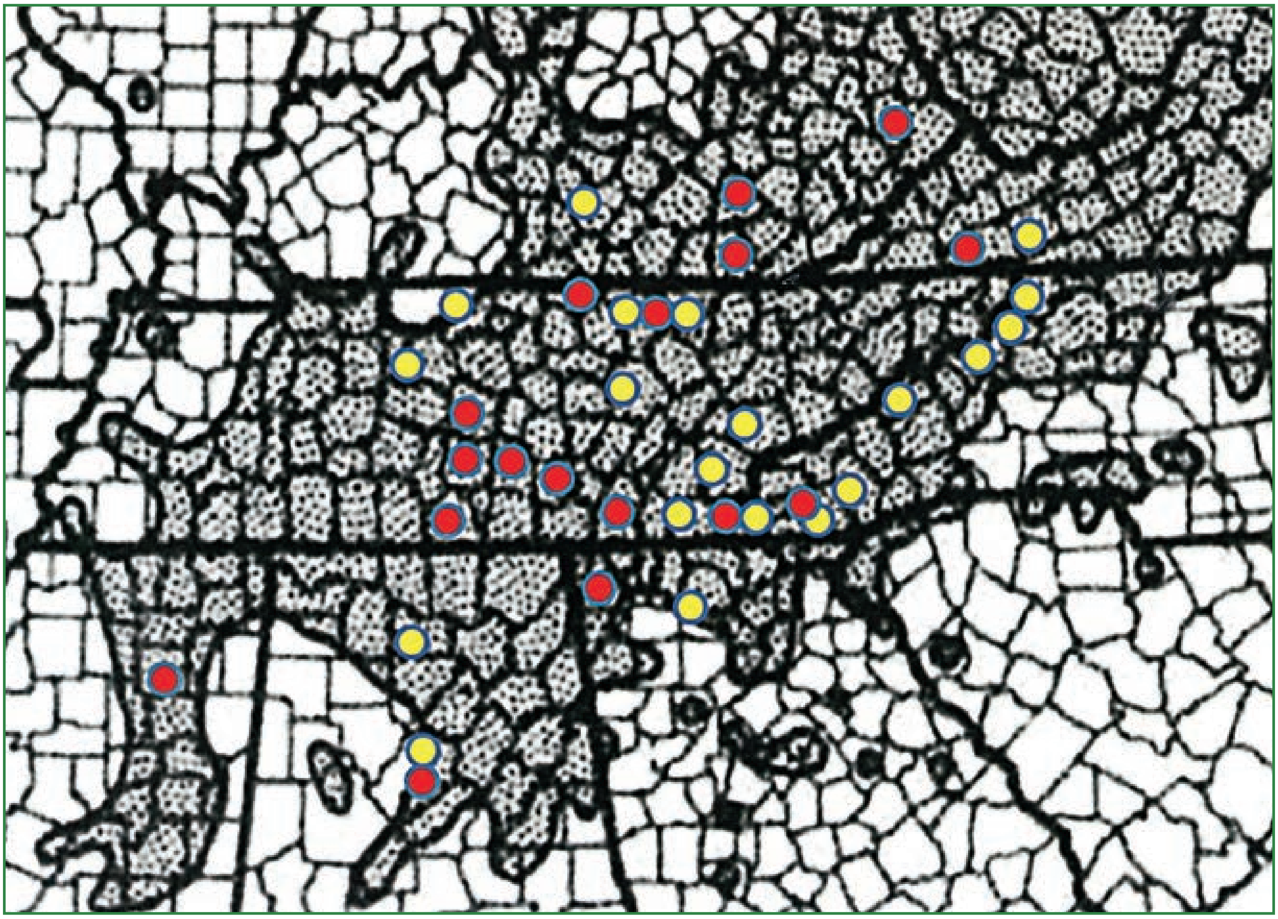


Figure 3. Chloroplast haplotype of American chestnut trees in the South that were tested by Li and Dane (2013), Shaw et al. (2012), and Sisco et al. (2014). Yellow circles represent trees having the 12 and 72 bp deletions indicated by the arrow in Figure 2. This is the most common chloroplast haplotype in the central and northern part of the range. Red circles represent American chestnut trees lacking these deletions in cpDNA. Each circle locates the samples to county and represents one or more trees tested in that county.

Europe, and Asia. Two deletion events of 12 and 72 base pairs (bp) were detected at one short region of the chloroplast genome (*trnT-trnL*) in American chestnut (Lang et al. 2006). Because these deletions were not found in the other *Castanea* species sampled, they eliminated 165 (14.2%) of the leaf samples submitted. The haplotype with this deletion was labeled D_2 by Shaw et al. (2012) and H_{D1} by Li and Dane (2013) (Figure 2).

More recent studies of cpDNA variation have shown that these two deletions in cpDNA are *not* a reliable trait for identifying American chestnut. First Dane (2009) showed that one Georgia population of Allegheny chinkapin also contained these two chloroplast deletions thought to be unique to *C. dentata* (Figure 2, type H_{P7}). Then Shaw et al. (2012) and Li and Dane (2013) reported that trees that were clearly American chestnut in bur and leaf morphology had several different chloroplast haplotypes, including haplotypes previously associated with Allegheny chinkapin. The haplotype with the 12 and 72 base pair deletions was the most common, especially in the Appalachian Mountains and in the central and northern parts of the range, but other haplotypes were often found in American chestnut trees in Tennessee, Georgia, Alabama, and Mississippi (Figure 3).

Conclusion

The biogeographic adaptability of the species is of utmost importance for the restoration of the American chestnut throughout the historic range of the species. Restoration effects should not be limited to trees with the most common American chestnut chloroplast haplotype but should also include the other chloroplast haplotypes associated with American chestnut in the South. Recently Sisco et al. (2014) found that the most common chloroplast haplotype of American chestnut was associated with pollen sterility in every interspecific F_1 hybrid examined when the American chestnut had been used as female in a cross to Asian chestnut species as male. When the cross was made in the other direction, with the Asian chestnut as female, the resulting F_1 hybrid had normal pollen shed. Pollen sterility was *only* associated with the most common American chloroplast haplotype – the haplotype that includes the 12 and 72 base pair deletions. When American chestnut trees having chloroplasts that did not contain these deletions were used as females in crosses to Asian chestnut trees, the resulting F_1 hybrids were male-fertile. This provides an even stronger argument for preserving American chestnut trees with the chloroplast haplotypes that are rare in the central and northern parts of the range but that are often found in American chestnut trees in northwestern Georgia, northern Alabama, central Tennessee, central Kentucky, and northeast Mississippi.

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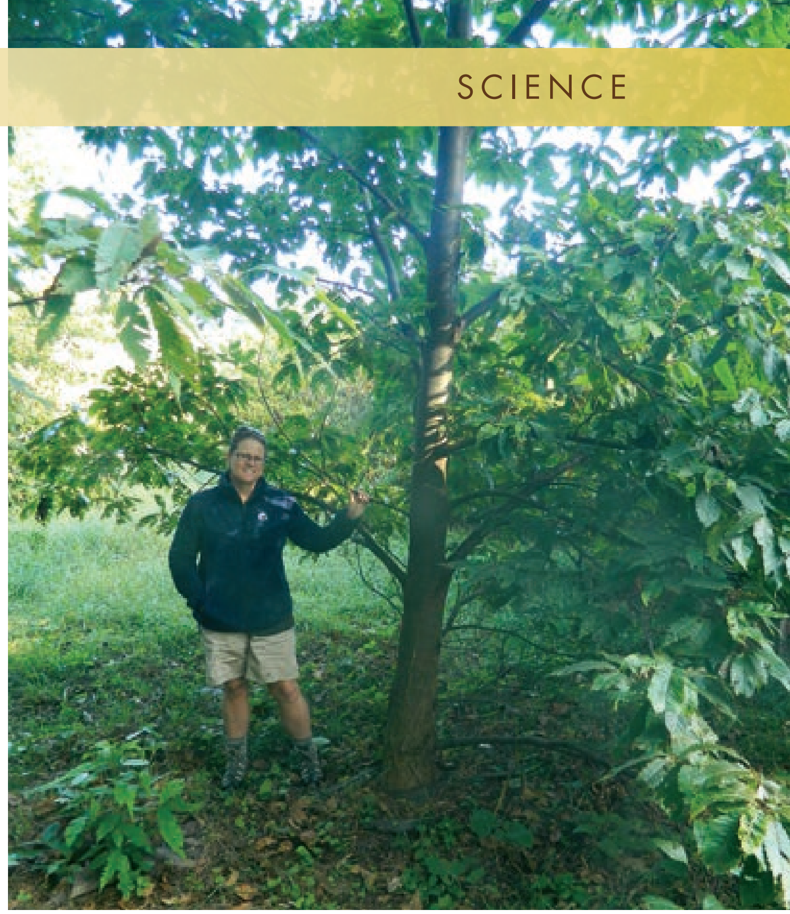
Regionally Adapted Seed Orchards within TACF's State Chapters

By Sara Fitzsimmons, Kendra Gurney, Dr. Laura Georgi, Dr. Fred Hebard, Matt Brinckman, and Tom Saielli



Sara Fitzsimmons stands next to one of the first PA-TACF regionalized B_3F_2 selections at the Penn State Arboretum. Planted in 2003, this tree exhibits vigorous callusing of inoculation points, which is an indication of a high level of blight resistance. Photo by Jeff Donahue

Several of TACF's Chapters have now planted **seed orchards**, also known as Legacy Tree Orchards,[1] and are one step away from producing regionally adapted, potentially blight-resistant American chestnuts. Seed orchards have been established in the Maine, Massachusetts/Rhode Island, Pennsylvania, Indiana, Maryland, Tennessee, and the Carolinas Chapters.

As Chapters begin seed orchard development, TACF volunteers and members are asking some astute questions about how to establish and maintain these plantings. Here we provide general information and updates to the original article on seed orchard establishment, published in *The Journal* in 2002 and 2003.[2] Additional information may be found online at http://ecosystems.psu.edu/research/chestnut/breeding/orchard-design, or by contacting a TACF Regional Science Coordinator.

Introduction to Seed Orchards

Forestry seed orchards can serve many purposes, including progeny testing (a way to determine parental quality), genetic gain (improving trait[s] of interest), capture of diversity, and seed production.[3] The purpose will determine both the design of a seed orchard and the mating design used to create the trees planted there. Although TACF's B_3F_2 seed orchards aim to serve each of those purposes, the most important among them is to capture the maximum amount of genetic diversity recovered by TACF's breeding with native American chestnuts trees.

How Many Selections to Use

In TACF's mainline backcross breeding plan, a minimum of six generations is needed to create a blight-resistant American chestnut. The seed orchard is the fifth of those generations. The parents of that generation, the fourth generation, are called B_3 trees[4] and are planted in orchards referred to as **breeding orchards**. Our Chapters have planted nearly 250 breeding orchards, representing approximately 50,000 trees. Over 300 native American chestnuts have been used as direct parents of those B_3 trees.

Within that fourth generation, each one of those 300+ native American chestnut trees is represented in what we call a **family line**. Assuming that blight resistance is controlled in an incompletely dominant fashion by three major genes, 12.5% of the nuts planted in each one of those B_3 family lines should exhibit moderate blight resistance, and could be selected for parenting seeds to plant in the seed orchards. The number of trees that are actually selected for further breeding depends on several factors and, within a given line, can vary from one to as many as ten.

Although several factors are considered when selecting for further breeding, the most important is blight resistance. The number of trees selected, whether nearby non-selected chestnut trees could contaminate the B_3F_2 cross, as well as how many family lines are present in a given orchard dictate whether we use open or controlled pollination techniques to produce the B_3F_2s that are to be planted in the seed orchard.

Open Pollination vs. Controlled Pollination

We plant A LOT of trees in our seed orchards (Figure 1). The main reason for this is that there is a very low statistical probability of obtaining a highly blight-resistant tree from this fifth-generation cross. Again, assuming that blight resistance is controlled in an incompletely dominant fashion by three major genes, only one out of every 64 seeds planted can have the potential for

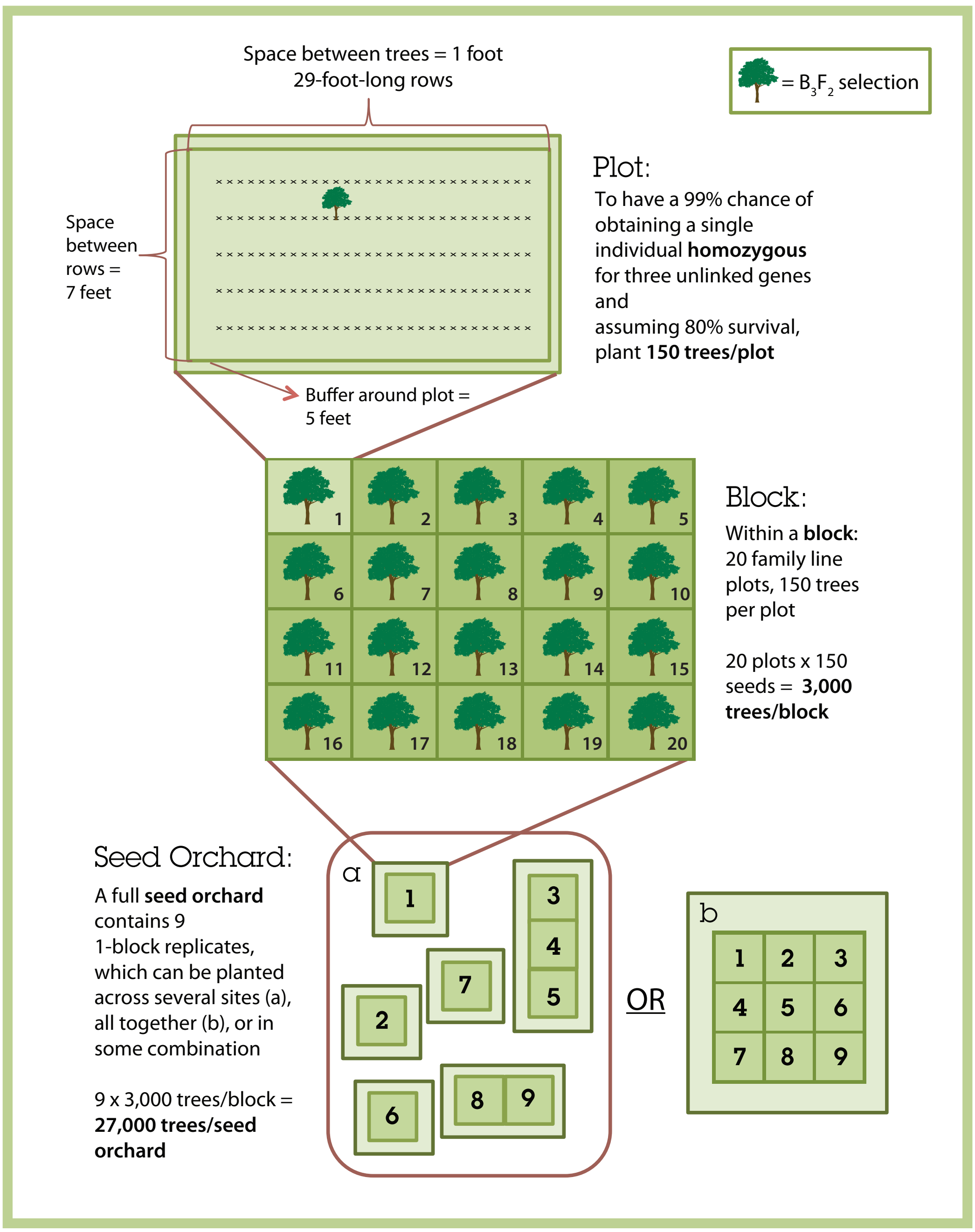


Figure 1. Seed orchard layout. How do we find that one homozygous tree per plot? See caption for Figure 2.

♂ pollen

♀ pistil

	RRR	RRr	rRR	RrR	Rrr	rrR	rRr	rrr
RRR	RRRRRR	RRRRRr	RrRRRR	RRRrRR	RRRrRr	RrRrRR	RrRRRr	RrRrRr
RRr	RRRRrR	RRRRrr	RrRRrR	RRRrrR	RRRrrr	RrRrrR	RrRRrr	RrRrrr
rRR	rRRRRR	rRRRRr	rrRRRR	rRRrRR	rRRrRr	rrRrRR	rrRRRr	rrRrRr
RrR	RRrRRR	RRrRRr	RrrRRR	RRrrRR	RRrrRr	RrrrRR	RrrRRr	RrrrRr
Rrr	RRrRrR	RRrRrr	RrrRrR	RRrrrR	RRrrrr	RrrrrR	RrrRrr	Rrrrrr
rrR	rRrRRR	rRrRRr	rrrRRR	rRrrRR	rRrrRr	rrrrRR	rrrRRr	rrrrRr
rRr	rRRRrR	rRRRrr	rrRRrR	rRRrrR	rRRrrr	rrRrrR	rrRRrr	rrRrrr
rrr	rRrRrR	rRrRrr	rrrRrR	rRrrrR	rRrrrr	rrrrrR	rrrRrr	rrrrrr

Figure 2. Punnett square showing all the combinations of alleles for blight resistance and susceptibility that could be inherited from two B_3 parents heteroyzgous at each of three loci for resistance. As can be seen in the upper left-hand corner, only one combination is fixed for resistance alleles (R) at three loci. It should be noted that we currently select our trees by examining canker expansion, which is the phenotype. Using only phenotypic data, it probably will not be possible to distinguish the one genotype with six alleles for blight resistance (in red) from those with five (orange) or four (yellow). We'll discuss this problem in a future issue of *The Journal*.

inheriting all six alleles for blight resistance[5] from their two B_3 parents (Figure 2); that is about a 1.5% probability of obtaining a suitable selection from any given seed.

Based on previously published calculations,[6] we estimate that at least nine B_3F_2 selections per family line will be required to capture most of the allelic diversity contained within the B_3 parent, which is why we plant nine complete seed orchard **blocks**, or **replications**. These nine blocks may be planted all together in one location, or they may be split across as many as nine locations. Assuming we have 20 distinct family lines (the goal for most Chapters working with a single source of resistance), and 150 trees per family line plot, using open pollination we need to plant 3000 trees per block.

To have a 99% chance of obtaining those nine replications from any one family line, we have to grow 1080 trees from which to select. Assuming 80% survival of seeds planted, that means we should plant a minimum of 1350 seeds for each family line. If we break up those trees into the nine blocks, that works out to planting 150 seeds per family plot (Figure 1).[7]

Controlled pollinations will allow less than 3000 seeds per block to be planted, but appropriate designs for such seed orchards are too complicated and numerous to describe here in detail. TACF's Regional Science Coordinators will work with Chapter volunteers and land managers to recommend the most appropriate mating and planting designs based on the number of B_3 selections and their locations. It is highly desirable that the selected mating and planting design be followed for any given seed orchard and all its component blocks. Otherwise, if pollination methods are mixed, it would be best to have each family line represented by 150 nuts, or 3000 trees per block.

With each family line being represented by anywhere from 1 to 10 B_3 parental selections, we have to choose which parents to use for any given cross, especially if using controlled pollination. We prioritize use of selections both by blight-resistance performance and also by American traits such as form, growth, and other species-specific characteristics. Because chestnuts reliably sprout from the root collar, backup selections can be clearly marked, pruned back, and allowed to re-sprout, just in case primary selections fail for one reason or another. It is better to use two or three parental selections within each family line rather than only one.

Layout, Maintenance, and Selection for Blight Resistance

One unique feature of TACF's B_3F_2 seed orchards is the layout. Based on the very low statistical probability of obtaining a highly blight-resistant tree from this intercross, many trees have to be planted in order to obtain a suitable selection (Figure 1). In the original design, 150 seeds from a given family line are planted in a five-row **plot** at a spacing of one foot between trees, and 7 feet between rows (Figures 3). This very tight spacing is used to achieve a final spacing of 30-35 trees per acre after all selections for blight resistance and other traits of interest are complete.

With the trees planted so closely together, TACF staff and volunteers must act quickly to perform selections. Inoculation with the blight fungus, then, occurs when the trees reach 1" in diameter at 12" above the ground.

This may occur as early as the second growing season! With the added stress from neighboring competition and being inoculated at such a young age, the trees have a more difficult time fighting off the intentional blight infection we use as our main selection tool.

Work is currently being done to quantify the effect of spacing and early inoculations. Meanwhile, there are several ways to alleviate some of the stress. One is to do a **staggered inoculation**, wherein we do an initial inoculation at age two or three with only a weakly pathogenic strain of the blight fungus, SG2-3. Based on the results of this inoculation, we can cull more than 50% of the trees in that plot. We then give the trees two more growing seasons and finalize selection with the strongly pathogenic strain of the blight fungus, EP155. Further culling after an initial screening with SG2-3 can also be based on the incidence and severity of naturally occurring cankers. Still another way to handle the stress imposed by narrow spacing and inoculation when

LAND OWNERSHIP

Planting a seed orchard plot on a Small Woodland Owners Association of Maine (SWOAM) property in Winthrop, ME, in 2013. Photo courtesy of Kendra Gurney

The life span of a TACF seed orchard can be as long as 45 years. There are no guarantees that any planting site will be available for that time period, and across TACF's Chapters the ownership of seed orchard blocks will be a combination of both public and private. The decision on where to plant ultimately comes down to who has the resources, personnel, and long-term commitment to see the project through to completion.

Land owned in perpetuity may be the most secure for such a long-term planting. This is most common for land trusts, educational institutions, and public lands. Of these, land trusts and other conservation groups may be the most secure. Universities can be great partners, but land conservation is not their primary focus and the possibility for the area to become a parking lot, dorm space, or used for other future development should be considered.

Private land is another option but it is good to explore long-term plans for ownership and management. A **conservation easement** or **restriction** that allows for chestnut orchard activities can be a good fit. Whenever possible, Chapters and volunteers should work with various types of agreements to ensure long-term stability of orchard management.

No matter the type of land, a written agreement or long-term management plan should be developed to address leadership or ownership turnover. An orchard manager should be designated to coordinate and oversee any activities spelled out in the agreement. TACF's Germplasm Agreement (GPA) is a good place to start. In addition, there are other types of agreements to consider, depending on the situation. In all cases, TACF recommends seeking legal counsel to review any signed documents.

1. Chapter Orchard Agreement (COA) – We recommend this for every planting, as a way to assign responsibility for maintenance, financial support or labor, access rights, etc.

2. Memorandum of Understanding (MOU) – An MOU is often a good idea when partnering with another organization for hosting an orchard, as it outlines each organization's responsibilities. Some organizations will sign an MOU for the entire time frame of the planting, or it may be written to be reviewed/renewed at a regular interval.

3. Other legal documents – Conservation Easements (CE), Conservation Restrictions (CR), and Lease Agreements (LA) may also be considered as additional legal leverage when working with private lands.

young is to increase the spacing between trees from 1 foot to 2 feet. Of course, without narrowing the rows, this also increases substantially the size of the planting area. Ultimately, the decision on how to establish the site, if different from the original design, should account for all other aspects of maintenance. A Regional Science Coordinator can help with those decisions.

Where to Plant and Land Ownership

The first step in establishing a B_3F_2 seed orchard is to find a place to plant. Although the number of trees to be planted can seem daunting, the amount of effort needed to maintain such a planting need not be overwhelming. Because seed orchards can be broken down into single **blocks**, as little as an acre can be planted. Anywhere from 1500 to 3000 trees may be planted in that space, depending on the use of open or controlled pollination, discussed previously. Once selection and culling are completed, some 10 to 20 trees will remain in the space and should produce regionally adapted, highly blight-resistant American chestnuts for years to come.

Figure 3. The Nature Conservancy's Basin chestnut seed orchard in Phippsburg, ME, showing one-foot spacing within a single plot of B_3F_2s. Photo courtesy of The Nature Conservancy

Trees take a long time to grow, and this can often affect the locations where we can plant our orchards. Most breeding orchards can be completed in the span of 10-15 years, but seed orchards often require as long as 30-45 years to be fully planted with all family lines, culled to highly blight-resistant selections, and ultimately, to produce all the seed needed for progeny testing, reintroduction, and restoration plantings. Such an extended time period can affect the locations where seed orchards can be established, and there is really no one answer as to what type of land ownership yields the best results in the long term – all cases have advantages and disadvantages. Luckily, TACF has several tools that can help Chapters, their volunteers, and partnering landowners reach agreement on these long-term issues (*see sidebar on page 18*).

How You Can Help

Our Chapters are always looking for volunteers to plant new orchard locations. If you are interested in becoming a grower, or helping to maintain one of our seed orchards, please contact your local Chapter and/or Regional Science Coordinator to find out how to get involved.

ENDNOTES

1. Call TACF's Asheville office to find out more about naming rights to Legacy Trees.

2. Hebard, FV. 2002. Meadowview Notes 2001-2002. *Journal of The American Chestnut Foundation*. 16(1): 7-18; Hebard, FV. 2003. Meadowview Notes 2002-2003. *Journal of The American Chestnut Foundation*. 17(1): 7-14.
3. For an excellent introduction to both seed orchards and forest tree breeding, see Zobel, BJ and J Talbert. 1984. *Applied Forest Tree Improvement*. John Wiley & Sons, New York.

4. In actuality, many of our Chapters have produced B_4s rather than B_3s, or a mix of the two. Here, for simplicity, we refer to all of these as B_3s and their generation as the fourth.
5. When all alleles are the same for a given trait, that tree is considered to be homozygous, or fixed, for that trait.
6. Hebard, Meadowview Notes 2001-2002.
7. This design does not insure that each block will have a selection, only that nine selections will be obtained. Transplantation between blocks may be needed in a few cases.

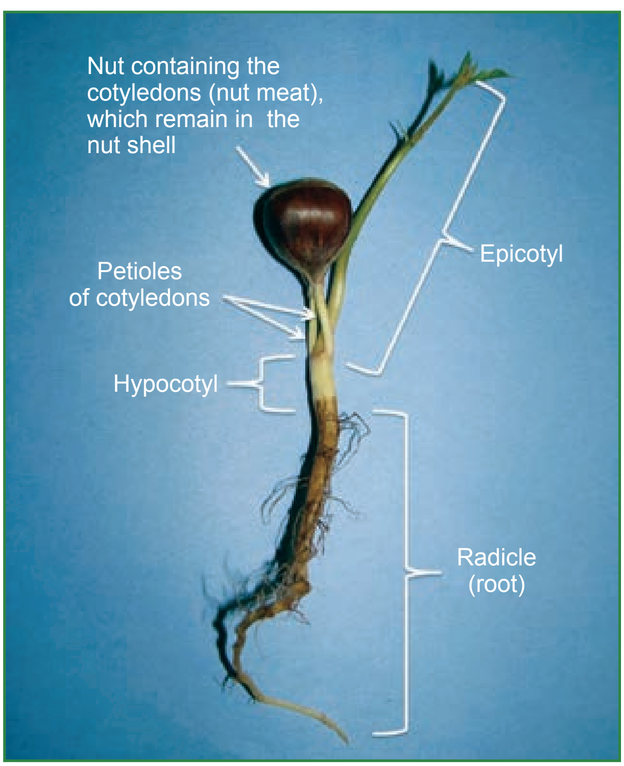
Grafting Chestnuts

By Dr. Laura Georgi, Dr. J. Hill Craddock, David Bevins, Robert Kling, and Dr. Fred Hebard

It occasionally happens that you have a chestnut tree that you'd like to copy in order to share it with friends; or perhaps you wish it were growing somewhere else, but it's too big to move. That is the case at Meadowview Research Farms' Wagner Farm in Southwest Virginia, where we have several large Asian and hybrid chestnuts that are important to our breeding program, but need to be removed because they are too close to the B3-F2 seed orchard there. In the spring of 2013, we made dozens of successful grafts of six of these trees and planted the grafts at the Price Farm.

Grafting Background

One grafting method that has some currency in the chestnut community is nut grafting, which involves cutting off the emerging seedling root from a germinating nut and inserting a twig, or scion, from the desired tree into the damaged nut (Jaynes and Messner 1967, Serdar 2009). This method destroys the seedling root system, and the success rate is quite low. We used two alternatives to nut grafting, which are described here: epicotyl budding (Ackerman and Jayne 1980, Jaynes 1980, Serdar 2009) and hypocotyl cleft grafting (Ackerman and Jayne 1980, Elkins et al. 1980, Serdar 2009). As the names indicate, epicotyl budding involves insertion of a scion bud into a stock seedling epicotyl, and hypocotyl cleft grafting involves insertion of a scion twig into a cleft hypocotyl. Unlike nut grafting, both methods spare the seedling root. Most of our grafts were of the former type, and our success rate was close to 80% before planting out in the orchard (Table 1). This method is suitable for grafting Asian chestnut scions onto Chinese chestnut seedlings, whose epicotyls are relatively stout. Chinese chestnut seedlings are less suitable as rootstock for American chestnut due to incompatibility that can lead to graft failure. Unfortunately, American chestnut epicotyls are slender, so it is difficult to bud onto them. Serdar (2009) describes a fourth method, inverted radicle cleft grafting, which he prefers to the other three (nut, epicotyl budding, and hypocotyl cleft grafting). We are hopeful that one of these methods will be suitable for grafting American chestnut buds onto American (and advanced backcross) chestnut rootstock. We plan to try cleft grafting American chestnut in spring 2014.



Parts of a chestnut seedling. Photo by Kendra Gurney

Preparation

Both epicotyl budding and hypocotyl cleft grafting require a certain amount of advance planning. For the rootstocks, you will need a supply of stratified seed, and they will need to be well-sprouted. We observed that the sprouts were stouter before they emerged from the peat in which the nuts were planted. Stout is good for budding, so you'll want to bury the nuts at least 1" deep; and you also will want to use a deep container, to give the taproot room to grow. It is important that the grafted trees have a good root system. You will need dormant bud wood (or scion wood) with fat, vigorous buds from the tree you want to graft onto the seedlings. Ideally, the twigs should be about the same diameter as the seedling rootstocks, but you don't want wimpy twigs with weak buds – hence the desirability of beefing up your seedlings. The dormant twigs can be sealed in zip lock bags and stored in a refrigerator.

Table 1: Grafts made in 2013

	Bud Grafts	Cleft Grafts
Grafts made: Total	163	14
Nanking	41	
Kuling	27	
Meiling	28	2
Jayne chinkapin	30	2
Armstrong	26	8
Glendale MAJ #7	30	2
Number planted out: Total	131 (80%)	4 (28%)
Nanking	27	
Kuling	19	
Meiling	28	1
Jayne chinkapin	16	
Armstrong	15	2
Glendale MAJ #7	26	1
Surviving, October 14, 2013: Total	102 (62%)	3 (21%)
Nanking	25	
Kuling	18	
Meiling	25	1
Jayne chinkapin	10	
Armstrong	11	2
Glendale MAJ #7	13	

In addition, you will need a good, sharp budding knife, budding tape, potting mix, and pots. We used peat pots, which minimizes disturbance when the grafts are planted out. Last year we planted seeds for rootstocks between March 12 and April 5, collected scion wood on March 27 and April 8, and made grafts between March 27 and May 1. This worked quite well for us (see Table 1). We might have started planting seeds earlier in the year and had a longer grafting season, but the scion twigs also need to have met their chilling requirement in order for the buds to grow when they are grafted onto the seedling. Hill Craddock joined us for our final grafting session, and allowed us to photograph him as he demonstrated the techniques.

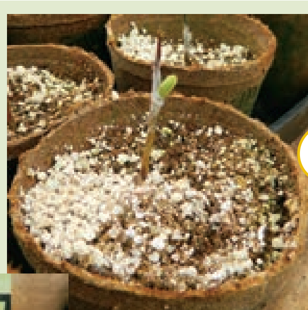
Hill Craddock begins his grafting technique with the Chinese chestnut seedling in his left hand (root stock) and the bud wood (scion) in his right. Also on hand, is a budding knife, budding tape, and pots.

Making an Epicotyl Bud Graft

1 To make a bud graft, a wedge is cut out of the lower stem of the sprout to accept the bud.

2 A matching wedge carrying a bud is cut out of the bud stick. The bud wedge needs to include enough of the stick above and below the bud so the graft can be securely wrapped. All cuts need to be smooth to permit close contact between the cut surfaces. A single stroke of the knife is best.

3 The bud is inserted into the slot in the seedling and wrapped with budding tape. One supplier recommends wrapping twice above the bud, once over the bud, and twice below the bud. The tape is elastic and is stretched as the graft is wrapped. It is important to keep the tape flat, and not twist it into a cord. The tape is designed to break down naturally in sun and weather, and a vigorous bud "should" be able to grow through it, but some grafters wrap around rather than over the bud or unwrap or (carefully!) cut the tape.



4 Once wrapped, the grafted seedling is potted up and placed in a sunny window or greenhouse. At grafting, or shortly thereafter, the top of the seedling rootstock is cut back above the graft. Otherwise, it will suppress growth of the grafted bud. Also, if your budwood came from an orchard with a history of gall wasp infestation, as ours did, watch out for swollen reddish sprouts! We had one of these. Fortunately, there was an axillary bud in the sprout below the gall, and it grew when we cut off the gall.

Making a Cleft Graft

1 To make a cleft graft, the top of the stock is cut off above the cotyledons and the stump is split between the cotyledons. In this picture, Hill Craddock has cut the seedling fairly high, but the cleft does reach the node between the cotyledons.

2 A piece of scion wood carrying a bud is cut to form a wedge, which is inserted into the cleft rootstock.

3 The graft is wrapped. You may have more success if you pot these plants with the graft above the potting mix. Moist conditions around a buried graft may interfere with the establishment of a successful union.

Planting the Grafts and Follow-up

Because we started our grafts in a greenhouse, they needed “hardening off” before they could be planted out. This entailed setting the pots out under the shade of larger trees and moving them out into more direct sun and wind over the course of a couple of weeks – with a hasty retreat to the greenhouse one night when there was a threat of frost in the forecast. When we finally set the plants out in the ground, we took care to trim back the top edge of the peat pots so they would not be exposed. If you are not careful, the projecting peat will wick moisture away from your plant and dry it out.

There is one VERY IMPORTANT consideration regarding grafted trees. The whole point of the exercise is to reproduce the scion. As long as the scion lives, you will have to be vigilant and remove any sprouts, or suckers, that emerge from the rootstock. Otherwise, the sprouts may supplant the scion, and you won’t have the tree that you wanted to preserve.

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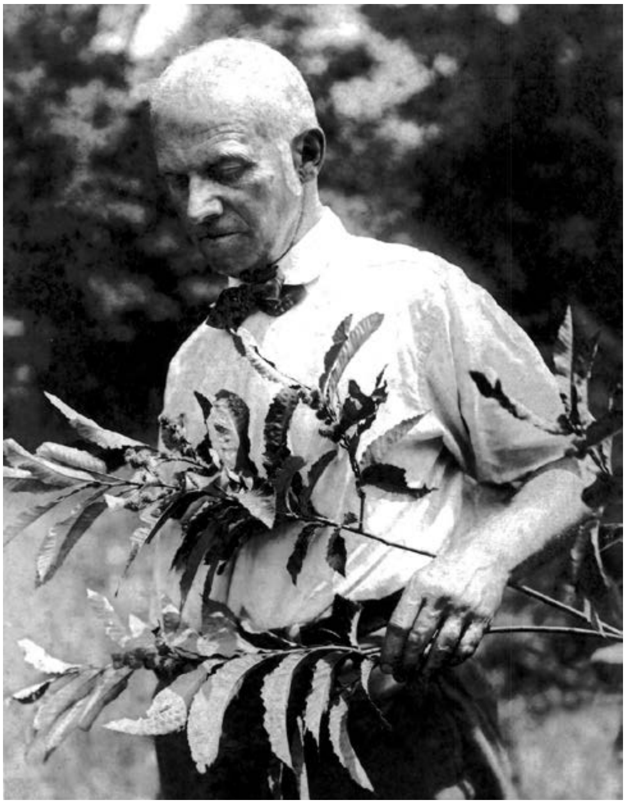


Dr. Robert Morris examines a chinquapin in his nursery circa 1930. Photo courtesy of Dr. Pam Walker

The Connecticut Chestnut Crowd

By Dr. Roger Gosden

IF the history of the American chestnut tree is ever put on stage it will be a tragedy in three acts. In the first act, a beautiful and bountiful tree is mostly taken for granted as an everyday sight in the countryside. Next, as the chestnut blight takes hold, there is panic and then grief as it disappears from forests across its range. In the final act, memories fade with the passing of the last generation that grew up with the tree.

When I moved to the Mid-Atlantic region in the 1970s and fell in love with the forests, I didn't know that a perfect tree was missing. No one told me. It was already half-forgotten because TACF didn't exist then. There is a societal amnesia for things that at one time were treasured and even supported communities, which Daniel Pauly, with ocean ecology in mind, called "shifting baselines." The principle applies to other environments, old cultures, and historic buildings, as well as iconic trees. Each generation draws a mental map of its *normal* environment from impressions formed when growing up, and may not even realize how much it has changed since it was pristine and is now impoverished.

We also forget many industrious and inspiring people who left the world a better place. Of course, we can't celebrate all of them, but as hopes are rising for the rebirth of the American chestnut tree in our forests it is good to remember endeavors of a century ago.

Only six years after the chestnut blight was first recorded in the Bronx Zoo in 1904, a group of amateur horticulturists met across from the park to inaugurate the Northern Nut Growers Association (NNGA). Two of its founders were already busy experimenting to save the tree, but their efforts were only brought to light recently when Pam Walker, the granddaughter of one of the men, Dr. Robert Morris, discovered his research notes browning with age while we were preparing his life story for publication (Roger Gosden and Pam Walker, *A Surgeon's Story - the Autobiography of Dr. Robert T. Morris* [Jamestown Bookworks, Williamsburg, VA, 2013]).

Bob Morris (1857-1945) was the NNGA's first president, an authority on orchard trees, and later wrote the classic textbook, *Nut Growing* (1921). He was also a notable naturalist, writer, and poet, which is an extraordinary achievement on top of his fame as a surgeon and

Merribrooke farmhouse, published in *The Guide to Nature*, September 1915.

The "Merribrooke melter" was the name given to the modified lantern Morris used to pour paraffin wax on grafts.

professor at the New York Post Graduate Medical School (later absorbed into Columbia and then New York Universities). Early in his career he was one of the first doctors to practice antiseptic surgery and his innovative bent extended across his career and hobbies. Despite eminence in medicine and a busy Manhattan practice, he found time for an even greater love of nature: "My light heart was out of doors; only my heavy feet remained in town" (R.T. Morris. *Fifty Years a Surgeon*. E.P. Dutton & Sons, New York, 1935).

Many fine American chestnut trees were succumbing to the epidemic on his Merribrooke estate of more than 400 wooded acres outside Stamford, CT, which he kept as a nature preserve. He hoped some hardy trees would survive for repopulating the woods, or that the blight's virulence would become attenuated, like scarlet fever. As these hopes faded in 1909, he started grafting and hybridizing trees on a parcel of land set aside as a nursery.

The "Morris method" was revolutionizing grafting in those days. He would pour paraffin wax from a "Merribrooke melter" to protect the union and developed an isotonic solution for keeping the scions viable before grafting. He often adapted techniques from human surgery, and the salt solution was analogous to one used for bathing human tissues; it anticipated plant cell culture by several decades. Chestnut branches or buds were grafted above or below ground on stocks of several species, but he was fondest of using chinquapins (chinkapins), which sprouted vigorously and flowered, although they eventually cankered. If he ever felt defeated after trying for more than a decade he never recorded it.

Hybridization experiments fared better than grafting. He had a large collection of native and foreign specimen trees, some of which were resistant to blight and candidates for cross-pollination. Reproductive isolation normally defines species but it does not necessarily rule out hybridization, and the chestnut genus (*Castanea*) is sufficiently promiscuous for cross-pollination, although the hybrid male flowers are often sterile. He bagged the female flowers of partners to avoid pollination by insects or wind and transferred pollen to their stigmata from anthers of Americans still flowering in his woods. The anthers sometimes needed sticking with boiled starch. Some five years after sowing he could identify the hybrids resisting the challenge of growing close to diseased trees.

Similar endeavors were being made a few miles away in Hartford, CT, by another great amateur, William Champion Deming (1862-1954). "Champy" is remembered for introducing the use of incubators for premature babies, but he was also a co-founder of the NNGA and passionate about nut trees. The doctors regularly compared notes from breeding experiments and lobbied for federal funding to fight the blight. A third member of the Connecticut crowd, Arthur Graves of Hamden (1880-1962), did not start working on chestnuts until years later, but he left an important legacy, to be described shortly.

Their goal now looks naïve, although the chances of success are impossible to calculate. To produce the perfect hybrid they needed many genes from the American to guarantee normal morphology and its prized nuts, plus an unknown number from the other parent to grant blight resistance. Drs. Morris and Deming used mostly Asian chestnuts as partners, as well as the smaller native chinquapin which is easier to manage. Not only did they cross these species with American

WELL-KNOWN MEMBERS OF THE NORTHERN NUT GROWERS ASSOCIATION

(Left to right): Willard G. Bixby, Baldwin, N. Y., Treasurer; J. F. Jones, Lancaster, Pa., Vice-President; James S. McGlennon, Rochester, N. Y., President; Ralph T. Olcott, Rochester, N. Y., Editor AMERICAN NUT JOURNAL; Dr. Robert T. Morris, New York City, former President; Dr. William C. Deming, Hartford, Conn., Secretary.

Officers of the Northern Nut Growers Association, printed in the *American Nut Journal*, September 1922.

chestnuts but also to each other for creating hardy orchard trees. Some trees flourished for up to fourteen years with only occasional pruning. Some chinquapin hybrids produced more than a single nut per bur, and tasted good. But these were exceptions, and Morris recorded "the ones [hybrids] which look most like the American chestnut also carry the parent's weakness in regard to blight" (R.T. Morris, *Chestnut Notes*, unpublished manuscript). Champy drew similar conclusions, although he wrote that the Chinese chestnut was "very promising as a nut."

In hindsight, their endeavors were far-sighted considering that the foundations of gene theory were new. Mendel's laws of inheritance had only been rediscovered in 1900, and the earlier theory of blending inheritance predicted that any benefits of crosses would be diluted in each successive generation.

Perhaps the men could have made more progress if they had recruited help from Thomas Hunt Morgan (1866-1945) who was pioneering animal genetics at their *alma mater*, Columbia University. Whether he would have suggested a backcrossing strategy with selection of resistant cultivars and intercrossing for creating a more wholly American tree is a moot point. Plant genetics was then in its infancy, and the strategy in the 1920s for producing new cultivars of barley by backcrossing would take much longer with trees than annual species. By this time the doctors were in their sixties and it was time to hand the baton to a younger man.

The impetus for Arthur Graves' work probably came from meeting a US Department of Agriculture scientist, Walter van Fleet, but it wasn't until 1930 that he began planting and crossing chestnuts. His work continued for three decades on a few acres of land in Hamden, CT, and he generated about 250 genetic combinations for testing by inoculating saplings with cultured fungus. Those created with the handsome Chinese chestnut were particularly successful because it had evolved with the fungus in northern China. His tree nursery eventually passed to the care of Hans Nienstaedt and Richard Jaynes at the Connecticut Agricultural Experiment Station (CAES) and afterwards to Sandra Anagnostakis, where it became the most inclusive collection of chestnut species and hybrids in the world. Some hybrids were transferred to a forestry experiment in the Lesesne State Forest in Virginia, while nuts and pollen were conveyed by Fred Hebard to Meadowview, VA, for the TACF program devised by Charles Burnham and Philip Rutter.

After retiring from medicine and becoming too frail for much outdoor work, Morris devoted more time to writing about nut trees and bringing them to greater attention as food crops. It was the time of the American Dustbowl and Great Depression, and as a Malthusian worrying that human population growth would outstrip food production he advocated a "Third Era of Agriculture" based on perennial crops, especially nut trees. The First Era of hunting and gathering had been succeeded by the Second Era of cultivated annual crops, but this had caused alarming soil erosion. With almost evangelical zeal he wrote that "Food crops from trees can supply all the requirements of a healthy diet for man and farm stock, and with less expenditure of time, money, and labor than annual crops…trees do not impoverish the soil as annual plants do…and do not require tillage" (R.T. Morris. *Fifty Years a Surgeon*. E.P. Dutton & Sons, New York, 1935).

His dream was shared with a friend, Professor J. Russell Smith of Columbia University and author of *Tree Crops: A Permanent Agriculture* (1929). On a tour of the rugged Corsican Mountains, Smith had seen prospering communities that were well-fed by the European chestnut forests (*Castanea sativa*), which produced chestnut flour and timber where few crops could grow. Since "farming should fit the land," Smith believed that permanent agriculture should be established in marginal land by growing tree crops that would also improve the soil.

A chestnut growing in what is now Mianus River Park, but was once a part of the Merribrooke estate. Photo by Roger Gosden

Morris was promoting nut trees as early as 1905 by offering cash prizes through competitions for the best nuts from seedlings. The disappearance of high-quality nuts from American chestnut trees must have been a heavy blow, but pecans, hickories, and other species promised bountiful harvests. Although nuts have not become a staple in our diet, there are now large industries for almonds in California, filberts in the Pacific Northwest, and pecans in the South. The men understood the problems of their day, but couldn't foresee that new cultivars, concentrated fertilizers, and selective weed killers would enormously boost agricultural production after the 1960s. This Green Revolution has pushed back the specter of world hunger and made grain crops ever more dominant. But with rising concerns about food security and quality we may yet see a larger future for tree nuts in our diet if they become more affordable. Philip Rutter of Badgersett Farm, MN, and a founder of TACF, is one of the modern advocates of what he calls, "woody agriculture."

I recently visited Morris's old estate with Pam Walker, accompanied by Sandra Anagnostakis (CAES) and Jerry Henkin (NNGA). Merribrooke, now part of the Mianus River Park, is still largely wooded and his tree nursery is probably overgrown. Afterwards, while preparing this article, I found an interview with him in a magazine from a century ago in which he declared, "What would I not give to return [to Merribrooke] for one whole day a hundred years from now on October the 5th 2012. Not in spiritual form with pure white wings and a golden harp, but just in my old duds." (*The Guide to Nature*, Vol. VIII, September 1915).

It was a strange coincidence that we had visited Merribrooke one hundred and one years later to the day. In the woods we saw crops of green burs lying on carpets of fall leaves and wondered if they were descendants of his trees; we'll never know. I imagine him overhearing our conversation: how thrilled he would be to hear about the latest generation of potentially blight-resistant chestnuts at TACF, how amazed to learn that hypovirulent strains of fungus studied by Sandra in Hamden can control the disease, and how astonished to see transgenic chestnuts now growing in the Bronx created by William Powell and Charles Maynard of SUNY College of Environmental Science and Forestry for neutralizing the blight's toxin. Since experimenters are natural optimists, as they must be, Dr. Morris might whisper in my ear that there are more than three acts in the history play about the American chestnut, and the fourth will soon be performed.

Dr. Roger Gosden retired as a Professor and Research Director at Weill Cornell Medical College in New York City to spend more time as a writer and Virginia Master Naturalist.

RECIPE

Chestnut Shortbread Cookies

By Mary Lu Sinclair

Ingredients

1 cup (2 sticks) butter, softened

½ cup sifted powdered sugar

1-2/3 cups all-purpose flour

1/3 cup chestnut flour

¼ teaspoon baking powder

A pinch of salt

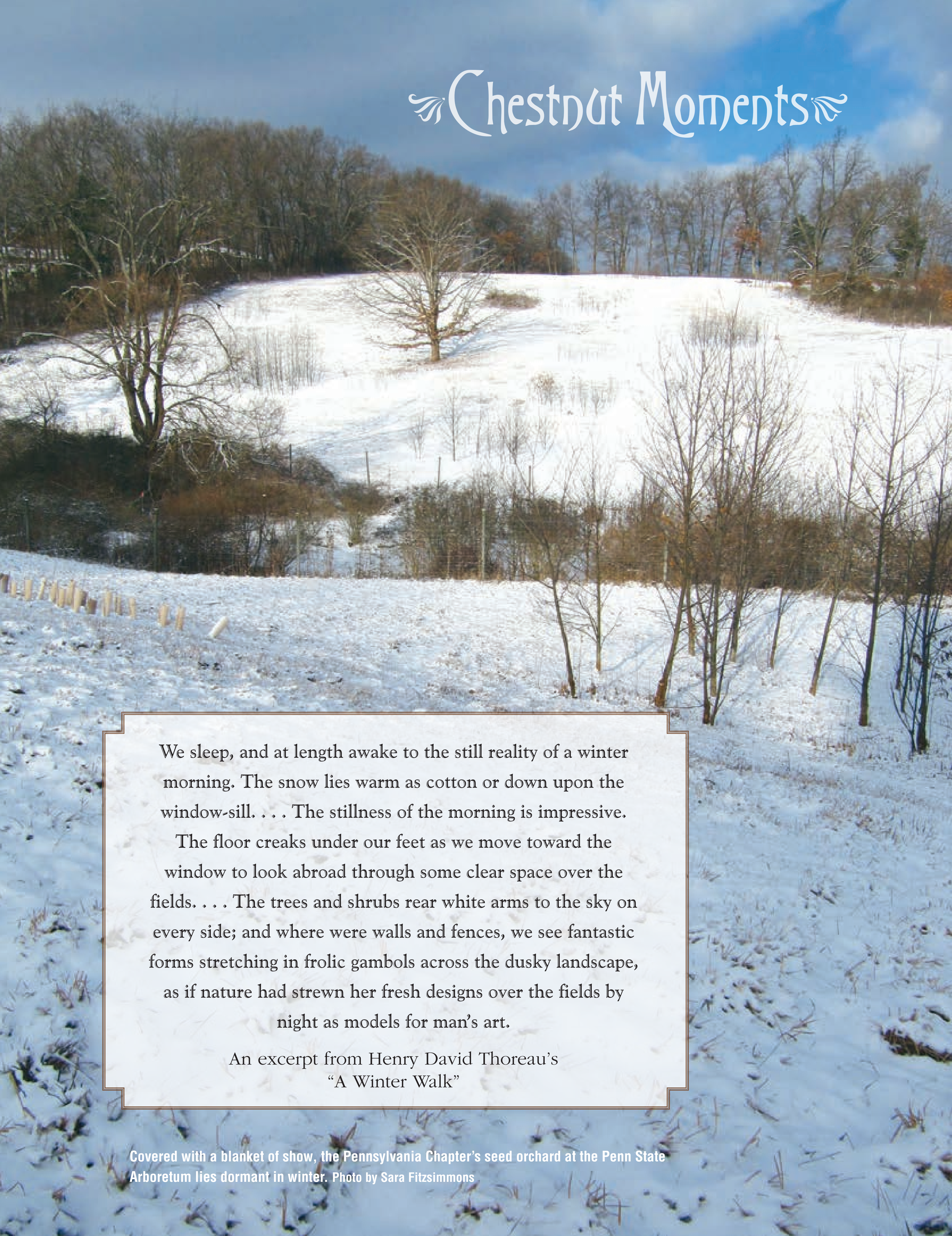
Mary Lu Sinclair is a member of the Connecticut Chapter and bakes chestnut shortbread cookies as part of a Heritage Walk that her husband, Ellery Sinclair, leads to the Chapter's Great Mountain Forest orchard in Falls Village, CT. "Several years ago a very good friend of mine shared the original version of this shortbread recipe, which used only wheat flour," said Mary Lu. "Later I had the idea to substitute a portion of the flour with chestnut flour, which I ground by hand with a nutmeg grater. My grandson (who was in preschool at the time) loved to help me with the grating. After he started school, I found a place in Ohio to order the flour."

Chestnut flour can be found at specialty food stores and ordered from many sources online such as Chestnut Growers, Inc., Nuts.com, and Allen Creek Farm.

Directions

1. Cream butter with sugar. Stir in flours mixed with baking powder and salt.
2. Spread out on baking sheet, or a cooking stone, to about ¼ inch thick; score into desired shapes.
3. Bake 20+ minutes at 300°F, until the edges are lightly browned.
4. Dough can be refrigerated, if needed.

Chestnut Moments



We sleep, and at length awake to the still reality of a winter morning. The snow lies warm as cotton or down upon the window-sill. . . . The stillness of the morning is impressive. The floor creaks under our feet as we move toward the window to look abroad through some clear space over the fields. . . . The trees and shrubs rear white arms to the sky on every side; and where were walls and fences, we see fantastic forms stretching in frolic gambols across the dusky landscape, as if nature had strewn her fresh designs over the fields by night as models for man's art.

An excerpt from Henry David Thoreau's
"A Winter Walk"

Covered with a blanket of show, the Pennsylvania Chapter's seed orchard at the Penn State Arboretum lies dormant in winter. Photo by Sara Fitzsimmons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