July 1997

Private Conservation Case Study

American Chestnut Foundation

Ronald Bailey

Natural History and the Blight

The American chestnut (*Castenea dentata*) was once the dominant hardwood species in Appalachian mountain forests, comprising as much as 40 percent of the overstory trees in the climax forests of the Eastern United States.[1] It has been said that an enterprising squirrel could once travel from Maine to Georgia on the interlocking branches of chestnut trees (see Figure 1, page 7). Visitors traveling toward the Appalachians from the coast could be fooled into thinking that the mountain peaks were snow covered when the chestnuts bloomed white in June. The fast growing American chestnuts often reached five feet in diameter and 60 to 100 feet in height. The trees were an extremely important source of food for wildlife including squirrels, wild turkeys, deer, bears and the now extinct passenger pigeon. The demise of the trees also brought reductions in the populations of wildlife that depended on chestnuts. Nevertheless, as important as the American chestnut was to the food chain, its loss did not lead to massive animal extinctions as some feared it might. Seven species of butterflies that fed on chestnuts exclusively are thought to have gone extinct.[2] Fossilized pollen indicates that chestnut trees had lived in North America for 40 million years.

The chestnut tree was greatly valued by pioneers for both its nuts and its straight, rot resistant lumber. The wood was easily worked and very useful for constructing long-lasting buildings and fences. Chestnut bark was a rich source of the tannins used to tan leather. Chestnuts have been called "the rice that grows on trees" because they have essentially the same nutritional profile as brown rice. Containing only 1% to 2% fat content, chestnuts are unique among nuts.

Then in 1904 disaster struck. That year forester Herman Merkel noticed that the American chestnut trees that lined the avenues of the Bronx Zoo were dying.[3] The Asian chestnut blight (*Cryphonectria parasitica*) had arrived and began to spread rapidly. The blight fungus was probably

brought to America on imported nursery stock of Chinese chestnuts. American trees had simply never evolved resistance to this parasite.[4]

The chestnut blight fungus spreads by spores that can be carried by the wind, birds, small animals and humans. The fungus invades trees at breaks in the bark or where dead branches are attached to the main trunk of a tree. The blight appears as an orange canker on the trunk of a tree. Once established the fungus rapidly "girdles" the infected tree, cutting off water and nutrients to the parts of the tree above the site of the infection.[5] It can kill a large tree within 18 months after the infection begins. Chestnuts still survive in Eastern forests as sprouts that grow from the roots of dead trees. These sprouts can reach 15 feet in height before they become infected. While these sprouts occasionally produce nuts, they are not enough to sustain a population of American chestnuts in wild over the long run.

After its discovery in 1904, the blight spread rapidly at about 20-50 miles per year. By 1950, the blight had devastated 9 million acres of forests by killing several billion American chestnut trees.[6] The species was essentially exterminated from Eastern U.S. forests. For the most part, the previous oak-chestnut forests have now become oak forests or oak-hickory forests.[7]

The danger posed by the blight was immediately recognized but all attempts to halt its spread failed. In one such attempt, the state government of Pennsylvania created a mile wide "firebreak" hoping to stop the onslaught.[8] It is possible that American trees that might have had natural resistance were destroyed in the panic engendered by the spreading blight as owners cut down their trees before they could be ruined.[9] The U.S. Department of Agriculture and the Connecticut Agricultural Experiment Station began breeding programs to try to create a blight resistant American chestnut. But neither program was able to create a tree that combined blight resistance with the desirable traits of the native tree. The USDA abandoned its breeding program in 1960 and the Connecticut Station stopped in 1970.[10] It looked like the American chestnut was doomed.

The American Chestnut Foundation to the Rescue

In 1983, a retired plant geneticist, Charles Burnham, then age 75, decided to take action. Burnham approached a number of biologist friends including Nobel Peace Prize Laureate Norman Borlaug and Peter Raven, the head of the Missouri Botanical Garden, to support a new private, non-profit organization dedicated to restoring the American chestnut to its native forests. Burnham and one of his former students, Philip Rutter, founded the American Chestnut Foundation (ACF) as a way of establishing and financing a private breeding program that would eventually create a blight resistant American chestnut.[11] Burnham was a distinguished geneticist who had made his career studying the genetics of corn at the University of Minnesota in St. Paul. Philip Rutter served as the founding President of the ACF and continues breeding chestnuts and hazelnuts in Minnesota on his farm called Badgerset.

In 1989, the ACF planted its first generation of crossbred trees on a farm leased from the Wagner family in Meadowview, Virginia. (Coincidentally, this is where I grew up.) The ACF hired a full-time plant scientist to direct the research farm.[12] Another farm in the Meadowview area was donated to the ACF by the Price family in 1995 and planted in 1996.[13] Consequently, the ACF now operates two farms with a total of 10,000 trees which are planted on 19 acres at the Wagner Research Farm and 12 acres at the Price Research Farm. These farms are overseen by two full-time plant geneticists. The administrative staff of the ACF consists of a full-time development director and executive director, along with the two staff scientists mentioned above.

The ACF is run by a volunteer Board of Directors comprised of scientists and business people who are assigned to either the Science Cabinet or the Development Cabinet. [14] There is also an Honorary Board of Directors headed by former U.S. President Jimmy Carter. And there are active state ACF chapters in Connecticut, Illinois, Indiana, Pennsylvania, and New York with plans to develop new state chapters in Maine, Maryland, and West Virginia.

Today the ACF has more than 2,200 individual members who pay regular annual dues of $40.00. The membership is kept informed through a quarterly newsletter *The Bark* and a more formal biannual scientific publication, *The Journal of the American Chestnut Foundation*. The ACF also holds annual conventions providing sessions on the science behind the breeding of blight resistant American chestnut trees, chestnut history and lore, and educational programs.

Members also participate in the breeding program. For example, some members volunteer for two weeks each June to help with the controlled pollination of trees on the two Virginia research farms. Other members participate in experimental planting programs in ten locations from Vermont to South Carolina. In addition, the ACF funds several external research grants, for example, to the University of Nebraska and Propagation Technologies, Inc. for micropropagation research; to the US Forest Service and the University of Massachusetts for genetic mapping; and to the University of Kentucky for research into blight resistance-related compounds. [15]

The ACF does not solicit government funds. Fred Hebard, who runs the ACF's farm in Meadowview, explained that "government funding is too fickle to support a long term project like restoring the American chestnut." Thus ACF members provided nearly 80% of the foundation's expenses in 1996 through dues, special appeals, and major private gifts. Most of the rest of the ACF's income was from grants provided by charitable foundations including the Pew Charitable Trusts (a three-year matching grant totaling $75,000) and the National Fish and Wildlife Foundation[16] ($25,000). The budget in 1996 was $278,000 and will increase to $375,000 in 1997.[17]

Bud Coulter, the current president of the ACF, says that early on the Foundation decided not to apply for government funding because “once you get the government involved, you have to follow their rules, file endless reports, and all that sort of stuff which become encumbrances that slow you down. And if you take government funds, it eventually becomes a government project.” Coulter does point out that Forest Service scientists have been cooperative and “have been very helpful to the ACF and

have made important scientific contributions which we appreciate." But he adds, "we think that it's better if we run the program and they (the Forest Service) cooperate with us, not the other way around."

The Breeding Program

The ACF's founder, Charles Burnham, devised the breeding program which the foundation is still following today. At age 75, he clearly knew that he would not live long enough to see the return of the American chestnut to its native forests. (Burnham died at age 91 in April, 1995.)

Basically, the ACF is crossing the American chestnut with the Chinese chestnut (*Castanea mollissimia*) which has strong resistance to the blight fungus. Chinese chestnuts can be infected by the blight but it does not kill them. Unlike American chestnuts, Chinese chestnut trees are squat trees that look something like old apple trees at maturity. Gnarly Chinese chestnut trees are certainly not towering, majestic shade trees nor are they sources of straight lumber. So the challenge for ACF geneticists is to breed trees that contain the genes for blight resistance but retain all of the other desirable characteristics of American chestnuts.

Initially, Burnham inquired about the USDA breeding program and was surprised to learn that USDA scientists had for some reason backcrossed their American/Chinese hybrids with pure Chinese chestnut trees.[18] This process might well result in blight resistant trees, but not ones that also retained important characteristics of the American tree.

Today, ACF geneticists have determined that blight resistance is carried on two genes which are only incompletely dominant. This means that full blight resistance is present only when both genes are present in both sets of chromosomes. If one chromosome contains both resistance genes while the other chromosome contains one resistance gene and one susceptible gene, then the tree would be only 3/4th resistant. The ACF breeding program is designed to create only fully resistant trees.[19]

The breeding program was explained as follows in the Summer/Fall 1996 issue of *The Journal of the American Chestnut Foundation* (see Figure 2, page 8):

> "Scientists working with the ACF predict that a chestnut at least 15/16ths American will exhibit virtually entirely American characteristics. Therefore, using Chinese-American hybrids--seedlings on average 1/2 Chinese and 1/2 American (F1 generation)--produced by those earlier breeders and at our Meadowview, Virginia research farms, at ACF we first backcross to an American parent. The result is a population of progeny on average 3/4 American and 1/4 Chinese (BC1 generation). We then backcross again -- for a population of progeny averaging 7/8 American and 1/8 Chinese (BC2 generation). By the third backcross, which yields a progeny on average 15/16 American and 1/16 Chinese (BC3 generation), we should reacquire the American tall-timbered growth habit and American adaptability."[20]

At each step the progeny of the crosses are inoculated with virulent forms of the blight fungus. Only seedlings that exhibit the greatest resistance are saved for further breeding. *The Journal* continues:

> "But every backcross, although necessary to recover desirable American traits, also reintroduces the genes for blight susceptibility from the American parent. In order to remove those genes, the next steps are intercrosses. In the first intercross, the most blight-resistant 15/16ths American trees are crossed with other blight-resistant 15/16ths American trees(BC3F2 generation). Again, only resistant seedlings are saved."[21]

ACF plant breeders also plan to test-cross the first intercross trees back to pure American stock in order to distinguish between intercross trees that are fully resistant and those which are only 3/4ths resistant. The test cross will reveal which intercrossed trees are fully resistant because such trees will yield a greater proportion of resistant progeny than will 3/4ths resistant trees. The final intercross will take place once the fully-resistant first intercross trees are identified through the test cross. This second intercross will yield the nuts that will begin reforestation (BC3F3 generation).[22]

The idea is to dilute out all of the characteristics of the Chinese great-great grandparent except for blight resistance. But creating one genetic line of blight resistant trees is not enough. American chestnuts grew in habitats ranging from Maine to Georgia, so it likely that distinct populations of chestnuts were adapted to particular soils, temperature ranges, day lengths, and moisture. The ACF breeding program is using American parent trees from all over the old range of the chestnut in order to preserve the American chestnut's genetic diversity. In addition, there are more than 100 different strains of the blight fungus. So, the ACF is incorporating blight resistance genes from different breeds of Chinese chestnuts to insure that the trees will be resistant to the different strains of the fungus and to protect against future pathogenic mutations in the blight fungus. [23]

Today, 2,216 third backcross, 15/16ths American and 1/16th Chinese trees are growing on the ACF research farms (BC3 generation). The ACF expects to harvest the first highly blight resistant nuts suitable for reforestation in 2005. Thus 101 years after the blight was first identified, the return of the American chestnut to Eastern forests will begin. By 2010, the ACF expects to have 40 different breeding lines producing nuts for reforestation.

In addition to the breeding program, the ACF is supporting some research on hypovirulence. In the 1950s, the blight appeared in Europe and although European chestnuts are a different species, it looked as though the American chestnut tragedy would replay itself there. But Italian biologists noticed that some of the infected trees were healing. The blight fungus taken from healing cankers and grown in petri dishes was white, not the characteristic orange of the deadly fungus. It turns out that this weaker form of the fungus had been infected with a virus which slowed the pace of its infection of chestnut trees. This process is called “hypovirulence.” Slowing down the blight allowed the chestnut trees time to build protective calluses which wall off the infection.[24]

In Europe, the spread of hypovirulence has essentially halted the epidemic there. Initially it was hoped that introducing the hypovirulent virus here would accomplish the same thing for American chestnuts. Scientists have isolated the blight-attacking viruses and have infected virulent forms of the blight with them. But this has not resulted in healthy trees. Today, research on how to use hypovirulence to help American chestnuts is ongoing with the support of the ACF.[25]

The Future

The ACF expects that they will have the first blight resistant trees that grow like American chestnuts in 2005--101 years after the blight was discovered in New York City. But that does not mean that the mission is accomplished. These blight trees will be tested for environmental adaptability. When the time comes, the ACF plans to release a series of lines of trees into the wild. "We are not going to put a monoculture into the forest," says Coulter. Once blight resistant lines are established, nurseries will be set up to provide seed for the various lines that will be reintroduced into the wild.

"If you're not a visionary, you don't have any business working with trees," says ACF president Bud Coulter. Sometime in the early part of the next century, as the result of the dedication of the ACF, the American chestnut will begin its return to its native forests thanks to private conservation.

This case study was written by Ronald Bailey, a freelance journalist and television producer in Washington, D.C. He is the author of ECO-SCAM: The False Prophets of the Ecological Apocalypse *(St. Martin's) and editor of* The True State of the Planet *(Free Press).* *The author wishes to thank Bud Coulter, the current President of the ACF and Tammy Carpenter, Membership Director for all their help and information on the history, science, and finances of the ACF.*

The Center for Private Conservation is supported by the William H. Donner Foundation.

Figure 1

Original distribution of the American chestnut tree (*Castanea dentata*).

Shoots from roots still occur throughout this range, but chestnut blight kills all the above-ground stems. (Illustration from Krebbs, 1994)

Figure 2

The American Chestnut Foundation's
Backcross Breeding Program

With each cross, additional American chestnut characteristics are regained. Only at the final cross, however, is blight resistance equal to that of the Chinese parent again reintroduced. (Illustration from Hebard, 1996).

ENDNOTES

[1]Krebs, Charles J., *Ecology: The Experimental Analysis of Distribution and Abundance*, (Fourth Edition, HarperCollins, 1994), p. 47.

[2]Budiansky, Stephen, *Nature's Keepers: The New Science of Nature Management*, (Free Press, 1995), p. 186.

[3]Cochran, M. Ford, *National Geographic*, "Chestnuts: Back from the Brink," (February, 1990), p. 134.

[4]Krebs, p. 47, Cochran, p. 132.

[5]Krebs, p. 47, Cochran, p. 132.

[6]American Chestnut Foundation information sheet, "History, Methodology, Successes, Organization & Finances, " February, 1996, p. 1

[7]Krebs, p. 47.

[8]Cochran, p. 135.

[9]Cochran, p. 135.

[10]American Chestnut Foundation information sheet, "History....," p. 1.

[11]American Chestnut Foundation information sheet, "History ...," pp. 1-2.; *The Bark: A Newsletter from The American Chestnut Foundation*, "ACF Founder Dr. Charles R. Burnham dies," Summer,1995, p. 1 & p. 3.; Ellingboe, Albert, et al., *The Journal of the American Chestnut Foundation*, "Tributes to Charles Burnham and Angus McDonald," Fall/Winter, 1995-96, pp. 10-16.

[12]American Chestnut Foundation information sheet, "History....," p. 2.

[13]*The Bark*, "Gift of Faith - The Glenn C. Price Research Farm," Summer, 1995, p. 1.; Coulter, personal communication, July, 1997.

[14]American Chestnut Foundation information sheet, "History...," p. 3.

[15]American Chestnut Foundation information sheet, "History...," p. 2.

[16] The National Fish and Wildlife Foundation is a 501(c)(3) non-profit organization established by federal charter. In some cases (e.g. their grant to the ACF) their grants trigger federal matching funds.

[17]Coulter, personal communication, July, 1997.

[18]*The Bark*, "ACF Celebrates Founder Charles Burnham's 90th Birthday," January/February, 1994, p. 1 & p. 4.

[19]Hebard, Fred, *The Journal of the American Chestnut Foundation*, "Backcross Breeding Simplified," Summer/Fall, 1996, pp. 35- 39.

[20]Hebard, p. 37.

[21]Hebard, p. 37.

[22]Hebard, p. 39.

[23]Hebard, p. 38.

[24]Cochran, pp. 135-137.; Coulter, personal communication, July, 1997.

[25]Coulter, personal communication, July, 1997.