HOW HAS THE AMERICAN CHESTNUT LAND COVER CHANGED IN THE EASTERN UNITED STATES?

CAN THE AMERICAN CHESTNUT RETURN TO ADAMS COUNTY, PENNSYLVANIA?

Abstract

The American chestnut has been considered to be one of the most valuable trees in the Eastern United States. Some of its many uses included buildings, fences, furniture, telephone poles, railroad ties, and nutrition for wildlife, livestock and humans. The American chestnut was the "redwood of the East" because of its 100 foot height and 12 foot diameter. Its wood was decay resistant, strong and straight. An analysis was made on the land cover change of this majestic tree in the eastern United States through the use of historical primary documents and current literature reviews. The paramount land cover time period of the American chestnut was during the nineteenth century where 40% to 50% of the forests in the eastern United States were chestnut. Once the invasive blight arrived to the United States, the land cover of the American chestnut practically disappeared. Researchers have spent many years trying to develop a blight-resistant tree. Thousands of test orchards have been planted, and owners are waiting to see if their breed of American chestnut will survive the blight that often attacks during the flowering stage. A field study was also composed on the Sachs Covered Bridge American Chestnut Orchard in Adams County. Six different backcrossed breeds are present in this orchard. An investigation was made to determine if there is a recommended breed to help increase the likelihood of the American chestnut returning to Adams County. Though it is still early and the trees have not reached maturity, the D130, D139 and the G136 are the breeds recommended due to their lower mortality rate and advanced growth rate.

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Introduction

The American chestnut (*Castanea dentata*) is a deciduous tree of the Fagaceae family. Other familiar trees of this same family are the oak and the beech tree. The American chestnut was described as the "redwood of the East". It is the fastest growing, widest, and tallest tree in the eastern United States. It can grow up to 100 feet tall with diameters beyond 12 feet. The wood is decay resistant, strong and straight-grained (Faison et al. 2014). Because of its size, the chestnut competes for water, nutrients in the soil and light. The type of environment this tree likes enables it to adapt very well to the eastern North American region. It prefers moderate climates, and it has high water requirements. It likes sloping topography with moist, well-drained lower slopes and rocky ridges (VTCNRE 2015). Favored locations would be sandy, loamy, well-drained and slightly acidic soil (pH 4.5-6.5) soil on mildly sloping fertile land. Full sun is also ideal for growth and seed production (PA-TACF 2006). The American chestnut lives longer and grows taller than the Asian species. It is not affected by late frosts because it flowers later than most deciduous trees (Jordan 2008).

The *Castanea dentata* was also known as a "cradle to grave" tree. Because of its strong rot resistant wood, societies used it for home building, fencing, cradles and coffins. During the late 19th to early 20th century, visitors came to the mountains for fresh air. Here they decided to build summer homes with the plentiful supply of American chestnut in the local forests. The wood and bark were used to build rustic "vacation architecture" of western North Carolina (Jordan 2008). The public loved its beautiful blondish and bold-grained wood. They not only adorned houses with it, but the wood was also used for furniture and instruments such as pianos (Horton 2010). American chestnuts were also used for telephone poles, fence posts, siding, and shingles because of its sturdy straight grain. The wood was perfect for outdoor use because of the large amounts of tannic acid found. Tannic acid hinders the rotting process of the chestnut tree. The fruit of the American chestnut helped the economy because shipments were sent to major markets in Philadelphia, New York, and Boston (VTCNRE 2015).

The Cherokee Native Americans had multiple medicinal uses for the American chestnut tree. They boiled leaves to make tea for heart trouble and typhoid, they mixed leaves with mullein and brown sugar to make cough syrup, and they placed the leaves on

wounds, and cured old sores with leaves from young sprouts. They also fed the nuts to a variety of wildlife—deer, rabbits, raccoons, wild turkeys, grouse, wild boar, mice, and squirrels (Jordan 2008).

In the 1800's nutting was practiced. Farmers, families, and friends went around clubbing sizeable chestnut trees, or they climbed up the 100 foot high trunks to strike the branches. Nuts were collected and converted into porridge, pan-fried bread, preserves, pickles and many other nutritional colonial dishes (Neimark 2015). The nuts tasted sweet and carrot-like. One could collect up to 6000 nuts off each tree. They were a perfect staple for humans, livestock and wildlife. They were high in fiber, protein, vitamin C, carbohydrates and low in fat (Horton 2010).

The American chestnut is no longer the populated tree that it was during the 1800's. How has the American chestnut land cover changed in the eastern United States? Can this "redwood of the East" once again inhabit Adams County, Pennsylvania?

Data and Methods

In order to find out how the American chestnut land cover has changed in the Eastern United States I investigated primary documents from earlier time periods and current literary reviews. I first examined land cover change of the eastern United States, then I narrowed the information to Pennsylvania, and lastly focused on Adams County.

I also met with Brad Yohe, a current American chestnut orchard manager, to gain information on whether or not American chestnuts have a chance of growing successfully in Adams County. I was able to collect data from the Sachs Covered Bridge test orchard on Pumping Station Road in Gettysburg, PA. There are six pedigrees of backcrossed chestnut trees in this orchard. The first generation seed is crossed with the blight resistant Asian chestnut tree. For the purpose of my data analysis, my question is, of the six pedigrees of American chestnut trees, which one would be the best to grow in Adams County in order to increase the likelihood of its survival? Tree height and mortality rate will be variables considered in determining the recommended pedigree.

I obtained the October 2014 height measurement and mortality rate data from Brad Yohe. The 500 trees were randomly planted in ten rows of fifty trees as shown in Figure 1. There are one hundred five A82 (code that the geneticist used) trees, one

Figure 1: Sachs Covered Bridge American chestnut orchard.

hundred eight D139 trees, one hundred ten D130 trees, ninety-five E77 trees, forty L70, trees and forty-two G136 trees. I grouped the data by their genetic code and calculated the mean of the growth. The higher the mean, the taller and faster the tree may grow. I also displayed them in the form of a box and whiskers graph because this will determine if the mean is elevated due to outliers. These data give a picture of how dispersed the heights of each pedigree are also. In order to see which pedigree displayed the best growth pattern, I looked for the highest median value because it separated my data in half. From this, I compared the data between the upper and lower quartile. Having a higher range in each quartile makes the tree height less predictable. I also calculated the 2014 mortality rate for each breed. From the analysis, I determined the best pedigree by looking for the lowest mortality rate and the highest mean. I also evaluated which pedigree exhibited the highest median with the lowest range in the upper quartile on the box-and-whiskers diagram.

To continue my field study, on November 7, 2015, I took a small team of students and parents to the Sachs Covered Bridge Chestnut Orchard to re-measure the 500 trees. I

calculated the mean for the 2015 data and created a side by side bar graph in order to make comparisons of the 2014 and 2015 data. A sign of a healthy breed of tree will have a higher average than 2014. I then generated a box and whisker graph with the 2015 data and compared it to the 2014 data to see if there was any change. Lastly, I determined the 2015 mortality rate for each pedigree and produced a circle graph to show the results. All these data were used to determine the best pedigree.

Results of American Chestnut Land Cover Change Literary Research

Pre-Colonial Land Cover of the American Chestnut

Prior to the blight it was believed that the American chestnut was the most common canopy tree in the eastern United States. Pennsylvania alone was comprised of 40 to 50% American chestnut. This was not always the case. Thompson et al. (2013) compared the modern forest data to historical vegetation data to quantify the Northeast region's shifts in land use. They analyzed witness tree markers found in archived landscape notes. Witness tree markers were used by colonial surveyors to identify locations. Ecologists have been using these for centuries to reconstruct the composition of the pre-colonial forest. In the pre-colonial maps, southern towns were dominated by oak and hickory where the northern towns were mostly spruce and fir. Contrary to the data that indicate the American chestnut was a major species in the eastern forest, pre-colonial data indicate an abundance of only a 3.3 percent. Figure 2 models that the most prevalent amount was found to be only 10 percent in the Appalachian region. This indicates an overstatement is often made on the prevalence of the American chestnut throughout the Northeast during the pre-colonial years (Thompson et al. 2013).

References by early explorers and naturalists in the eastern United States verify the lack of American chestnuts. John Smith from the New England coast states mentions oak as the dominant tree (Faison et al. 2014).

> Oke [oak], is the chiefe wood, of which there is great difference in regard of the soil where it groweth; fir, pine, walnut, chestnut, birch, ash, elm…, and many other sorts (Smith 1616).

> Chestnut trees grow very tall and thick, mostly, however, in mountainous regions and high land (Colonel William Byrd of Virginia (1737).

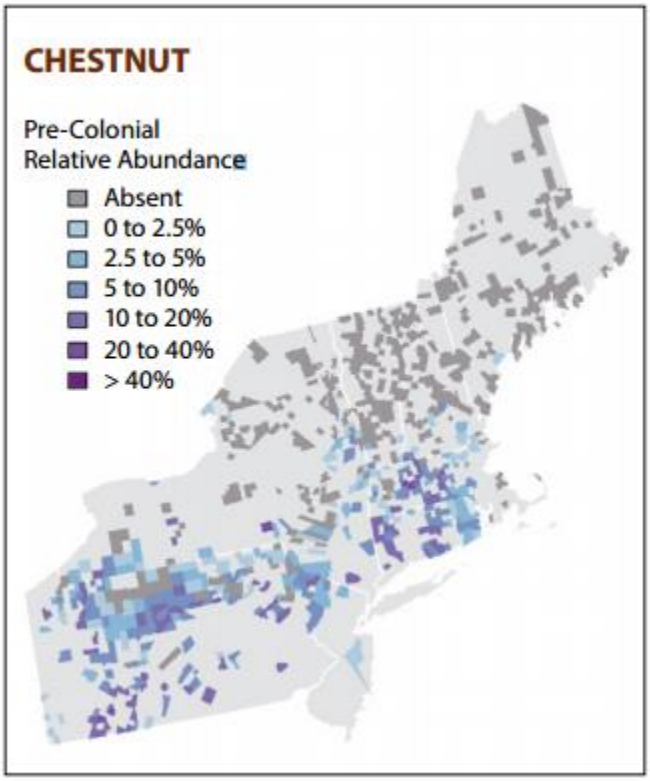


Figure 2: Pre-colonial abundance of the American chestnut tree (Thompson et al. 2013).

Understory burnings have been practice for more than 10,000 years by the native people. Areas were cleared along waterways and settlements making it easier to travel. Around 1650 land cover in the northeast changed due to logging and agriculture (Thompson et al. 2013). By the 1750's European settlers burned vast amounts of forest for agriculture—as much as 75%. By 1850 farmers abandoned their fields to move west. They were enticed by the Louisiana Purchase, the California Gold Rush and modern transportation. Trees replaced the idle farmland (Jabr 2014).

Colonial Land Cover of the American Chestnut Prior to the Blight

By the nineteenth century uncontrolled logging of the American chestnut ironically promoted the population growth of the tree in the eastern United States. The trees capability to sprout shortly after being cut enabled the trees to adapt to the intense logging practice (Fraison et al. 2014).

Early Connecticut foresters Hawley et al. (1912) stated

> This sprouting capacity of the species is it strongest characteristic, and the one by which, with each successive cutting, it gains in the struggle for existence with the rival inmates of the wood lot. Trees sprout to a more advanced age than any other species, and vigorous sprouts are common on specimens 110 to 120 years old…. The chestnut is one of the most rapid growing New England trees. The young sprouts are especially fast growing, often making a height of five or eight feet the first year….On account of its wide use and consequent value, its ability to sprout and its rapid growth, the chestnut was the most valuable tree of southern New England, until the bark disease appeared.

This statuesque tree was now located anywhere from Northern Florida to Southern Maine, from Tennessee to Ohio as indicated in Figure 3. It had a diameter more than 10 feet and a height that can be higher than 100 feet (VTCNRE 2015). There were nearly four billion trees covering more than 30 million acres. The average lifespan was two the three centuries (Horton 2010).

The American chestnut became the most common canopy tree in the eastern United States. It represented 40 to 50% of the canopy trees in the southern Appalachian

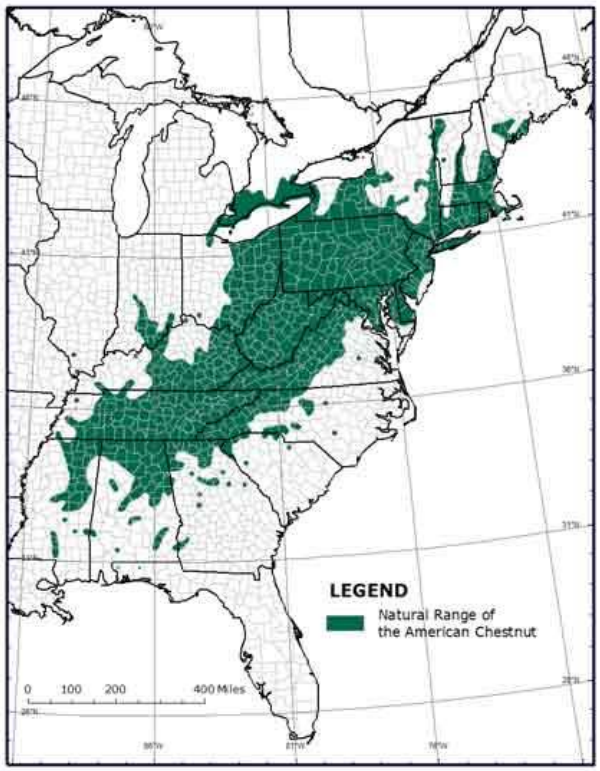


Figure 3: Land cover of the American chestnut tree prior to the blight (TACF).

forest, and it was the dominant tree of the Blue Ridge Mountains. The chestnut was the prevailing tree in the southern Appalachian riparian forests because of its density, abundance, and basal area. It was the major contributor to the woody debris loadings in the Appalachian streams (Vandermast et al. 2002).

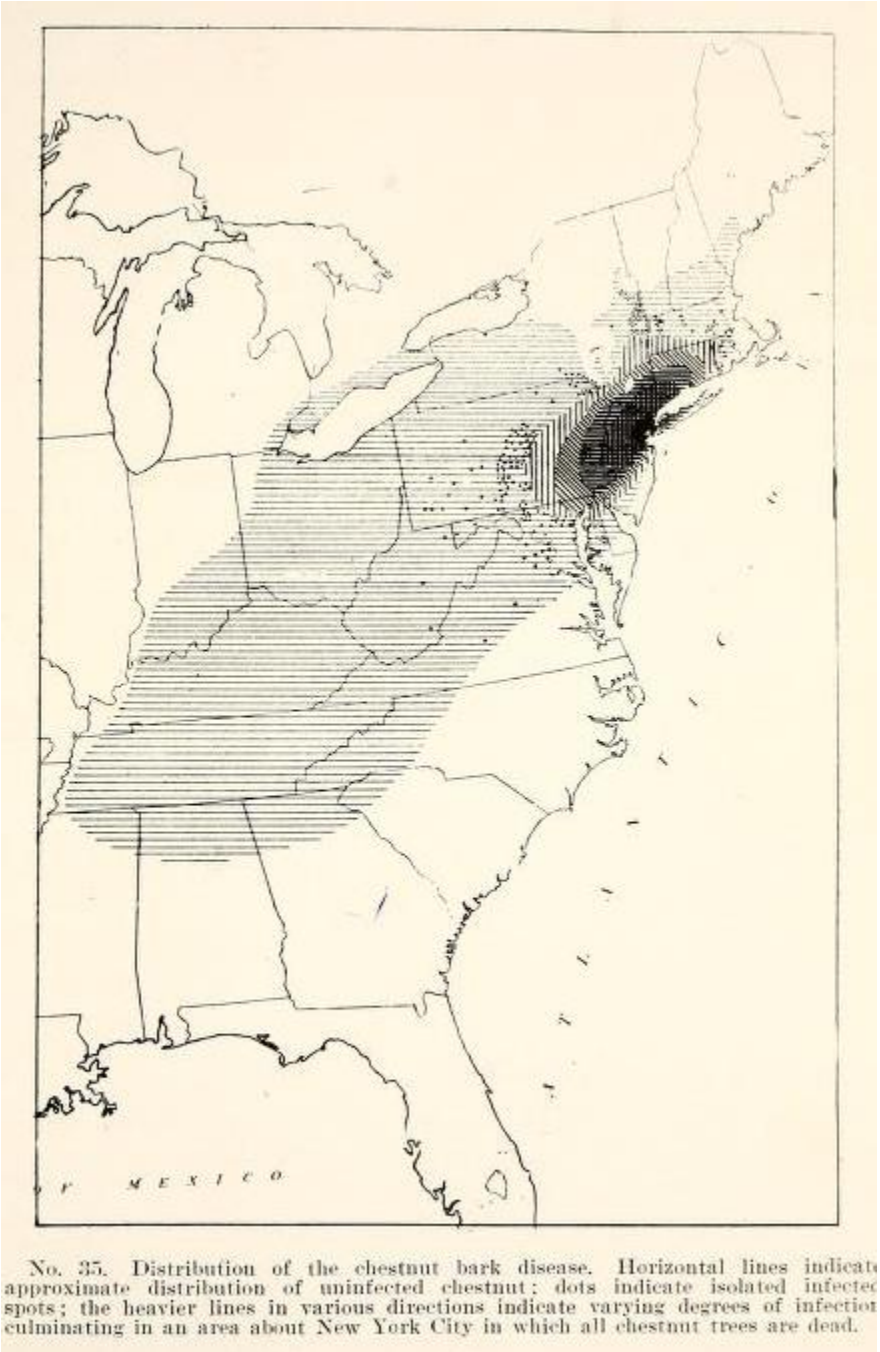
Blight Era-Land Cover Change throughout the Eastern United States

Chinese and Japanese chestnut trees were being imported into New York in 1876 by nurseryman S.B. Parsons because customers wanted something exotic. Around 1904 the nurseryman noticed a fungal blight infecting and destroying the native chestnut trees in the area. Within the first four years the blight spread up to Poughkeepsie, New York and central New Jersey. Horticulturists planted imported chestnuts in the Delaware Water Gap as an experiment to see if they were what was causing the harm. As a result the blight spread swiftly through Pennsylvania (Price et al. 2012). The historical map found in Figure 4 identifies the distribution of the blight through the eastern part of the United States. By 1912 one can see the heavy mortality of the American chestnut throughout Pennsylvania, New York and New Jersey.

Around the same time the blight started, there was a huge increase of timber harvesting. During the 1920's and 1930's as the blight was traveling across the eastern United States, the demand for American chestnut lumber was amplifying. Landowners were urged to cut any chestnuts on their land to help hinder the disease and to profit from the lumber that most likely will be lost to the disease (Burke 2011).

Logging could have potentially affected the pathogen infection rates and expedited disease spread because of the decrease in structural diversity. As a result, there is a relationship between land use and chestnut decline. Areas that were purposely chosen to be logged for chestnuts impacted the abundance of today's chestnut. Resistant healthy trees could possibly have been removed from the population (Burke 2011).

By the early 1940's approximately 300,000 square miles of the American chestnut were destroyed. An estimated 4 billion trees were killed. By 1950 almost all of the chestnuts were gone. Figure 5 shows the timeline of blight movement throughout the



No. 35. Distribution of the chestnut bark disease. Horizontal lines indicat approximate distribution of uninfected chestnut; dots indicate isolated infecte spots; the heavier lines in various directions indicate varying degrees of infectio culminating in an area about New York City in which all chestnut trees are dead.

Figure 4: Historical map from the blight commission indicating the distribution of the chestnut disease (Guilbert 1912).

eastern United States. People and forests had to adjust to this land change (Faison 2014). The blight made an economic, devastating impact—especially in the Southern Appalachians. Mountain families had no source of food or cash because they relied on selling nuts during the holidays in the city market. Farmers were not able to feed the

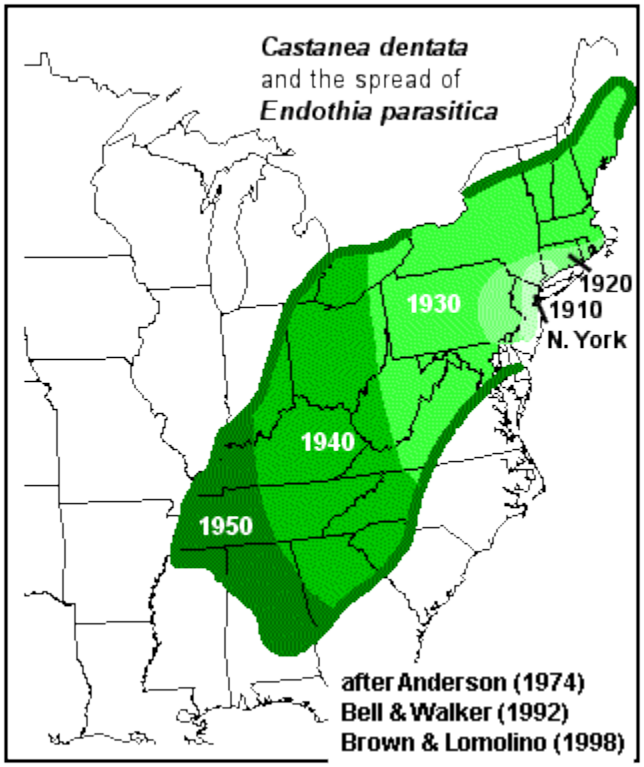


Figure 5: Timeline map showing the spread of the blight throughout the eastern United States.

farm animals that relied on the nuts for daily nutrition throughout the winter months. (Jordan 2008).

The impact of the loss of American chestnut trees due to the blight changed the composition of the types of trees found in the eastern United States. American chestnuts were so dominant that they often did not give less competitive trees the chance to mature. Because of their size, chestnuts competed for water, nutrients in soil and light. Once they died this allowed the slower growing trees to take over the forest (VTCNRE 2015). Land cover changed from 80% of it being American chestnut and oak to sun-loving saplings, blackberries, and greenbriers. Maples, tulips and oak became more numerous. Animals had to adapt to this new environment because they no longer could rely on the nutritional chestnuts. The passenger pigeon became nonexistent once its sustenance was no longer available, and they no longer could roost on the mammoth branches to protect themselves from human hunters (Jabr 2014).

Land Cover Change in Pennsylvania after the Blight

In Pennsylvania most of the counties' forest land cover was comprised of 40% to 50% American chestnut prior to the blight. Today the US Forest Service estimates 0.04% of Pennsylvania trees are American chestnut. Most chestnuts are in the form of sprouts from stumps from the stricken trees. These sprouts eventually will become infected and die because of the blight by the time they are eight years old (Price et al. 2012).

Historical documents show how concerning the loss of the American chestnut was to the state of Pennsylvania. The blight reached Pennsylvania by 1908.

> In 1911, the Pennsylvania State Legislature passed a bill authorizing the Governor (John K. Tener) to appoint a Commission of five citizens for the purpose of thoroughly investigating the Chestnut Tree Bark Disease which is rapidly destroying the chestnut trees of the Commonwealth (Guilbert et al.1912).

$275,000 was allotted to this panel to scientifically investigate and devise ways and means to destroy the disease. An urgent request came out asking other states to be involved with the panel because their states were not yet touched by the blight (Maine, Vermont, New Hampshire, New Jersey, Delaware, Maryland, and others south and west). The committee met in Harrisburg on February 20, 1912 (Guilbert et al.1912).

> This Conference has been called for the purpose of obtaining all possible information concerning the best methods of fighting the destructive fungous disease known as the chestnut tree bark disease or the chestnut tree blight, which was first detected in the neighborhood of New York City about eight years ago, and has since spread to the Northeast as far as Eastern Massachusetts, and to the Southwest as far as Central Pennsylvania, Maryland and Northern Virginia (Guilbert et al.1912).

Governor Tener stated the value of the trees in Pennsylvania was worth forty million dollars. For Virginia the value was thirty-five million dollars. Industries depended on the chestnut tree. Tannic acid found on every part of the tree was used in the tanning industry. Telegraph and telephone companies depended on the trees for poles, and railroad companies were greatly dependent on the trees for railroad ties. The loss of the tree would hurt the economy when thousands of men were out of jobs. Real estate owners would eventually see the value of land diminish. The governor believed that the chestnut

was so valuable the Pennsylvania forests could not get along without it. Forest management would never be the same. There was major concern over what the removal of this tree would do to the future of forests. Dr. Russel Smith stated how everyone was influenced by the American chestnut. He asked those around him if they wore shoes because the tannin for the leather was made from chestnut. He asked if they read because the pulp remnants of the tannin was used to make paper. Do they rent a house? Chestnut wood was found in many homes. Do they use the telephone or telegraph? Chestnut was used for the stately poles. Do they own a farm or town lot? Chestnut was often used in the fence post to mark property. The nuts were also very valuable. In Italy a chestnut crop was more prosperous than wheat or corn. The estimated three hundred million dollars loss was most likely underestimated. He concluded that more money was needed to restore this valuable tree (Guilbert 1912). Panic could be inferred in the voices of these men over the concern for this valuable tree. Figure 6 shows an archival map indicating counties infected with the blight in Pennsylvania. The heaviest distribution of

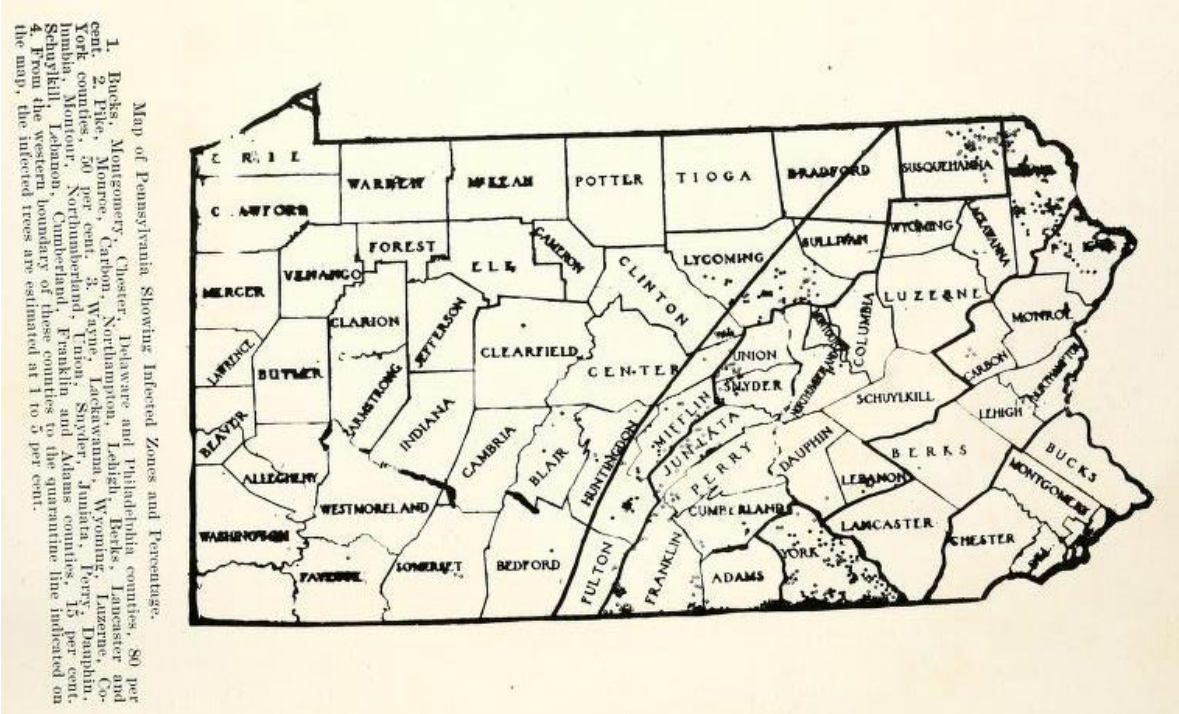


Figure 6: Archival map from the blight commission indicating the infected land cover areas in Pennsylvania (Guilbert 1912).

The disease at this time (1912) was Bucks, Montgomery, Chester, Delaware, and Philadelphia Counties. All government efforts to control the blight ended by 1915 (Faison et al. 2014).

Pennsylvania has since recovered from its forest devastation. Today it is one of the states with the most forest land cover. Pennsylvania has regained about 17 million acres of forest over the past twenty years. The trees today are the northern hardwoods of oak, hickory, yellow birch, maple, beech and black cherry. The forests are considered young for they started growing between 1900 and 1960 on the abandoned farmland and the severely logged forest land (Price et al. 2012).

Land Cover Change in Adams County before and after the Blight

Historical documents from 1886 were found regarding the land cover in Adams County prior to the blight. In the History of Cumberland and Adams Counties archives it was stated by Bates et al. (1886):

> This mountain, which forms the western boundary of the county, separating Franklin and Cumberland Counties, is a range beautiful in all its wonderful variety of outlines and magnificent scenery, as also in all its drear monotony and desolation. This mountain range, once covered with a rich and dense growth of forest trees, is now largely denuded of its primeval treasures of timber. This denudation of mountain forests is due, in a measure, to the wholesale and often wanton destruction of timber by the woodman's ax; but in a much larger measure this "abomination of desolation" is caused by the great fires that periodically sweep over the mountains, leaving hideous sears behind them, to mark the track of the devastating fiend. Sometimes one sees for miles and miles, the ground covered with the charred and prostrate trunks of once lordly trees. Great lofty pines and oaks, whose stems are blackened from the roots upward as high as the fire has reached—huge, distorted and disfigured, stand gloomily above their moldering brethren, their black skeletons extending their dead and broken arms, in mute testimony of lost grace and beauty. Nothing could be more desolate than those "burnings" (Bates et al. 1886).

Prior to the blight era this eastern region was known as the "Barrens" when it was first settled by the whites around 1729. No large timber was present due to the burnings by Indians. This practice was used every few years to clear the underbrush which helped the hunting operations. Only dwarf trees and low underbrush could be seen for miles (Bates et al. 1886).

> In consequence this treeless waste received the name "Barrens," which name it has ever since retained. After white settlers occupied the soil these conflagrations ceased, the open country becoming in the course of time well timbered, magnificent forests of oak, hickory and chestnut standing where formerly there was only barrenness….The same is said to be true concerning a large scope of country lying northward of Gettysburg….The fact has been pretty well established that the destruction of forests and the clearing of land, which have been going on rapidly in the county during the last fifty years or more, have affected the rainfall and climate unfavorably….The forests of the county are noted for the variety, beauty and value of their trees. Among the most common may be mentioned the oak, hickory, chestnut, walnut, elm, gum, birch, beech, pine, sycamore, poplar, hemlock, tulip, cedar, maple, dog-wood, iron-wood and many others (Bates et al. 1886).

According to the Bates et al. (1886) archives the blight had not yet affected the area; however, much of the forest area was devastated from burning and timbering. Once the blight hit the area, there may not have been as many trees as other parts of the state. Information from Figure 4 indicates only 15 percent of the trees in Adams County were affected by the blight during the blight commission (Guilbert 1912).

What Was This Devastating Blight?

The name of this invasive fungus is *Cryphonectria parasitica*. The fungus forms a bright orange rounded structure on the surface of the chestnut tree bark. Two types of spores are produced—ascospores which can be carried by wind and conidia which can be transferred through water drops on birds, squirrels, or insects (Jordan 2008). The wind-borne fungal spores seep through cracks of the tree bark. The fungus kills the vascular cambium and phloem and eventually leaves a girdling, sunken canker in the tree. The canker hinders the tree from transferring the food it makes through the photosynthesis process causing the tree to die. It destroys the vascular systems that carry sap. The root system is not affected by the blight and as a result sprouts shoot up to form new chestnut trees, but these eventually die from the blight once they reach the reproductive age (Faison et al. 2014).

Environmental Benefit of the American Chestnut

Since the blight, scientists have spent decades researching and experimenting on ways to produce a blight-resistant American chestnut. The goal is for this tree to

maintain the characteristics of stature, growth rate, and adaptation. What makes the American chestnut such a valuable icon to justify spending so much time, money and effort on its recovery? As stated earlier the chestnut provides shelter and nourishing meals to wildlife. Their leaves are more nourishing to wildlife than oak leaves. When leaves fall into streams their leaves infuse all their chemicals. The leaves of the American chestnut decay more quickly than oak leaves allowing an abundance of nutrients for aquatic larvae of numerous insects. Crane fly larvae prefer eating American chestnut and maple leaves over oak leaves. The leaves have more phosphorus, nitrogen, potassium and magnesium than leaves from other trees. Hardy chestnut branches that fall into streams provide underwater shelters and hiding locations for fish more than the rapidly disintegrating oak branches. The soil beneath the chestnut had as much as 17 percent more carbon and nitrogen. Chestnuts returned more nutrients back to the earth where they can be used by other plants, animals and organisms (Jabr 2014). Duke Energy is one of the major funders for the chestnut revival. They are especially interested in reclaiming coal mining land. One main reason for wanting to restore these colossal trees is because of the impact they make toward the carbon sink. Because of their size, growth rate, and longevity, chestnuts store more carbon at a faster rate than any other hardwood (Horton 2010).

Biotechnologist from the State University of New York College of Environmental Science and Forestry (SUNY) have worked diligently at developing a genetically modified seed. Researchers from The American Chestnut Foundation (TACF) have cultivated the backcrossed breeding method, and the Recurrent Selection Timber Research Program's (RST) is working to produce a timber type American chestnut tree. Volunteers throughout the eastern United States have planted tens of thousands of trees in order to recover this valuable tree. Chestnut orchards are identified in Figure 7.

Genetically Modified Seeds

The biotechnologists from SUNY transplanted a gene that other plants such as wheat, barley, cocoa and some fruits have that enable them to have freeze tolerance, disease resistance and more fruit production. The gene causes an enzyme to be produced that impedes the fungus destruction. The gene was transplanted into the chestnut embryo

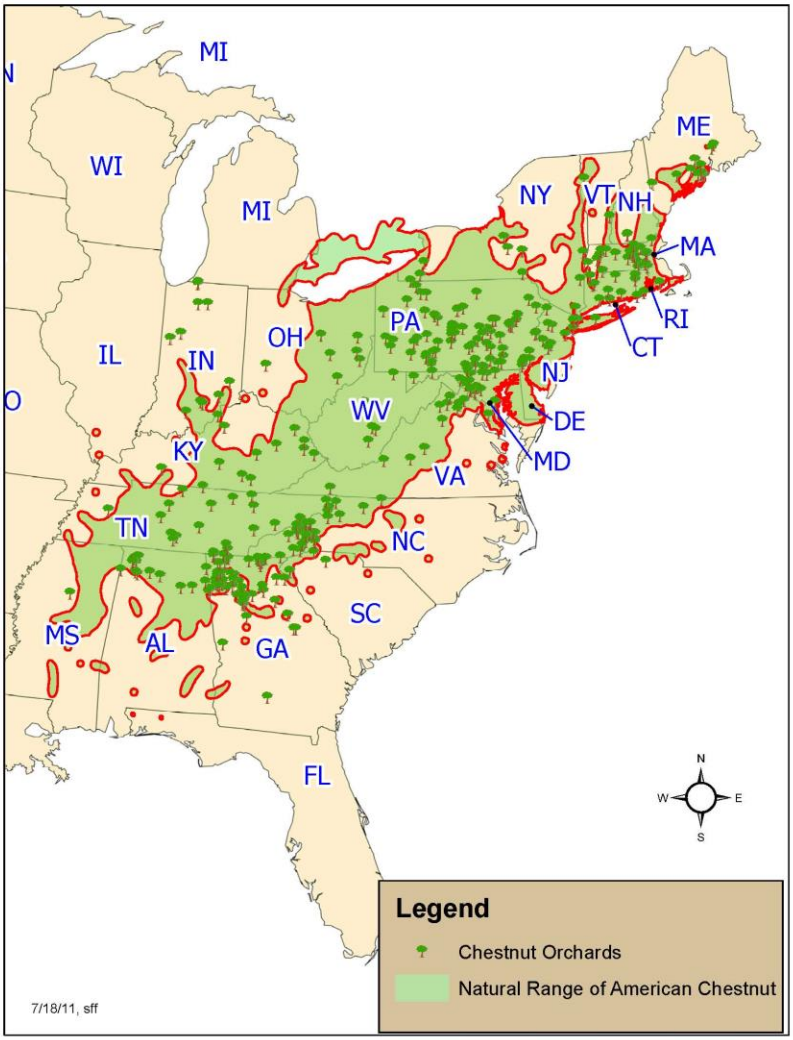


Figure 7: New American chestnut orchards throughout the eastern United States (TACF)

of a surviving sprout, then they took the harvested cells to grow a new embryo which would become the seedling (Neimark 2015). The biotechnologists transferred the resistance-enhancing genes through *Agrobacterium*-mediated transformation. This genetic transformation allows complete control over which genes can be inserted. For example the transgenic American chestnut 'Darling 4' is currently showing blight resistance. The pollen from the 'Darling 4' is used to produce transgenic T1 seedlings which are also showing resistance toward the blight. Advantages of the outcrossed transgenic seedlings are faster initial growth and increased genetic diversity because there is more control over the genes used in this method compared to the backcross method where there is little control. There is the debate of whether the genetically modified fruit

is safe for consumption. Studies so far have shown that the food crop is considered safe for humans and wildlife (Newhouse et al. 2014).

Backcrossed Breeding Method

Three scientists, David French, Charles Burnham and Philip Rutter, not only started The American Chestnut Foundation in 1983 but had also instituted the Meadowview research farm in Virginia. Here they used a hybridization technique where they used successive crosses of offspring from an American chestnut and the blight-resistant Asian chestnut. The first cross is an offspring that is one-half American chestnut genetically. The second cross is between the 50-50 hybrid and the pure American chestnut. The result is a tree that is 75 percent American. When crossed again the result is 87.5 percent and again is 93.75 percent American chestnut. When the tree is several years old it is inoculated with the chestnut blight to test its immunity. The reproductive process of the trees in the orchards are managed manually where each female part of the flower is bagged with pollen from a specially bred tree (Middleton 2015). The current Restoration Chestnut is 94% American backcross hybrid. Trees that show the best blight resistance are used to start another generation. Plantings have already taken place throughout national forests, private property, abandoned strip-mined sites and across the Appalachian Mountains (Horton 2010). There have been more than 120,000 seeds of the Restoration Chestnut 1.0 produced. This breed of chestnut is believed to be the one to successfully survive the blight and still have the similar characteristics to the pre-blight chestnut. Results will not be known for another five years as to how well they resist the blight (Middleton 2015).

Recurrent Selection Timber Research Program (RST)

This research program started in 2004 under the guidance of Dr. Robert Leffel, retired USDA Research Agronomist and Pennsylvania TAMF (PA-TACF) scientist. This program's goal is to produce a blight-resistant timber type tree. The process involves using controlled pollination crosses of American and Asian chestnut trees. Several pedigrees are produced from the first generation. Isolated seed orchards promote natural intercrossing of trees. The benefit of this process is that tedious hand pollination is not

necessary. Additional generations are planted in future orchards (F2. F3, Fn). Timber selection is not able to occur until the trees are at least 12 years old then a timber evaluation can be made. Backcrossing is not necessary but could be a future application once the blight-resistant timber chestnut tree is produced (PA-TACF 2014).

Adams County Test Orchard

Test orchards throughout the Eastern United States are collecting data in anticipation to see which backcrossed seed or genetically modified seed can surpass the age of the blight infestation which is about 5 to 8 years from now. There are many American chestnut enthusiasts in Adams County, Pennsylvania desiring to start growing these trees on their property. One such orchard is found in Gettysburg on Pumping Station Road along Marsh Creek. The Sachs Covered Bridge Chestnut Orchard was planted in the spring of 2014 with 500 second generation (F2) trees that were part of the Recurrent Selection Timber (RST) Program. There are six pedigrees of backcrossed chestnut trees in this orchard. Brad Yohe, former science coordinator of Carroll County School District, and Jim Peters, his successor, have initiated a partnership with TACF and Maryland Public Schools. More than 9,000 students have been engaged in a STEM curriculum involving hands-on chestnut tree explorations. Grant support was also received from the Chesapeake Bay Trust, the United States Forest Service and the Maryland Forest Service. The Sachs Covered Bridge Chestnut Orchard is the result of this project (Peters et al. 2015).

Results of the Field Study

My field study analysis indicates in Figure 8 that the mortality rate for A82, D139, D130, and E77 were very similar, 15 to 16%. The pedigree with the highest mortality rate of 26% was L70. G136 had the lowest mortality rate of 12%.

The 2014 and 2015 mean data for each pedigree reveals in Figure 9 that the breeds with the largest mean are D130, D139 and G136. The lowest mean is found with E77 and L70.

The data from the 2014 and 2015 box and whiskers graphs as shown in Figures 10 and 11 show that the highest medians have continued to be pedigrees D139, D130, and

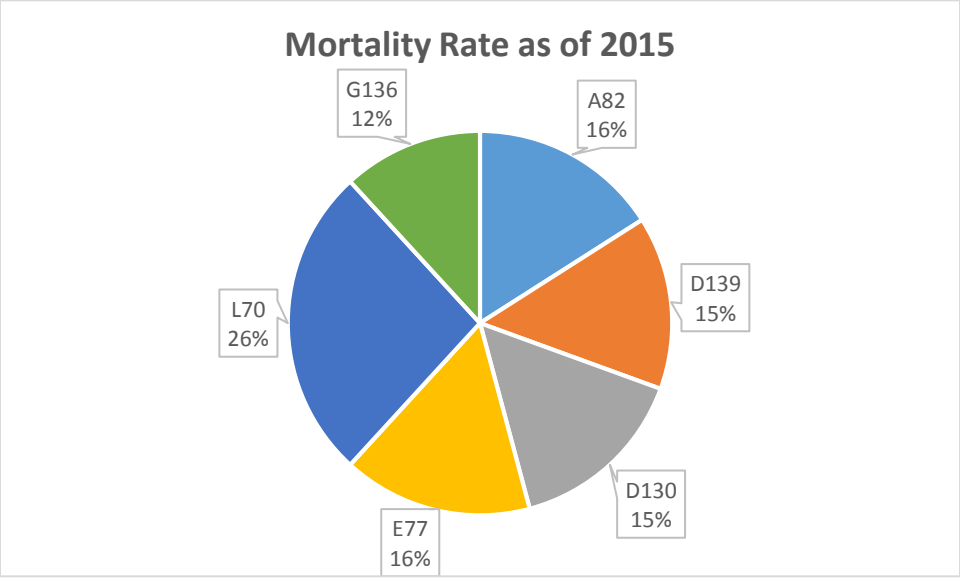


Figure 8: 2015 mortality rate for the six pedigrees.

G136. All three display the most compact upper quartile indicating these pedigree have a more predictable growth pattern and will most likely grow the fastest and tallest.

I would recommend that the three pedigrees D130, D139, and G136 be used together in future orchards because of their current low mortality rates and their

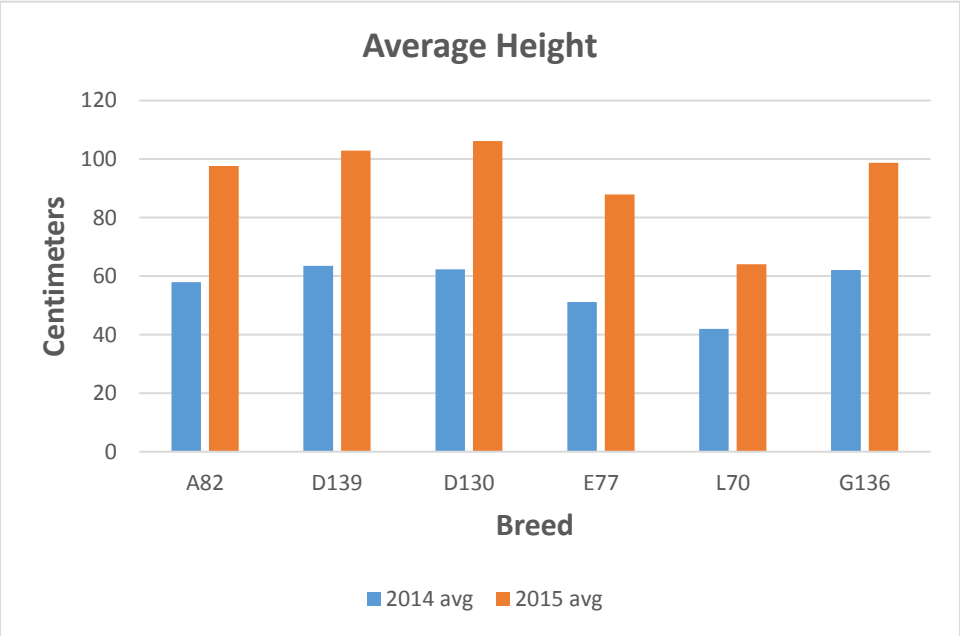


Figure 9: Comparison of the 2014 and 2015 mean height of each pedigree.

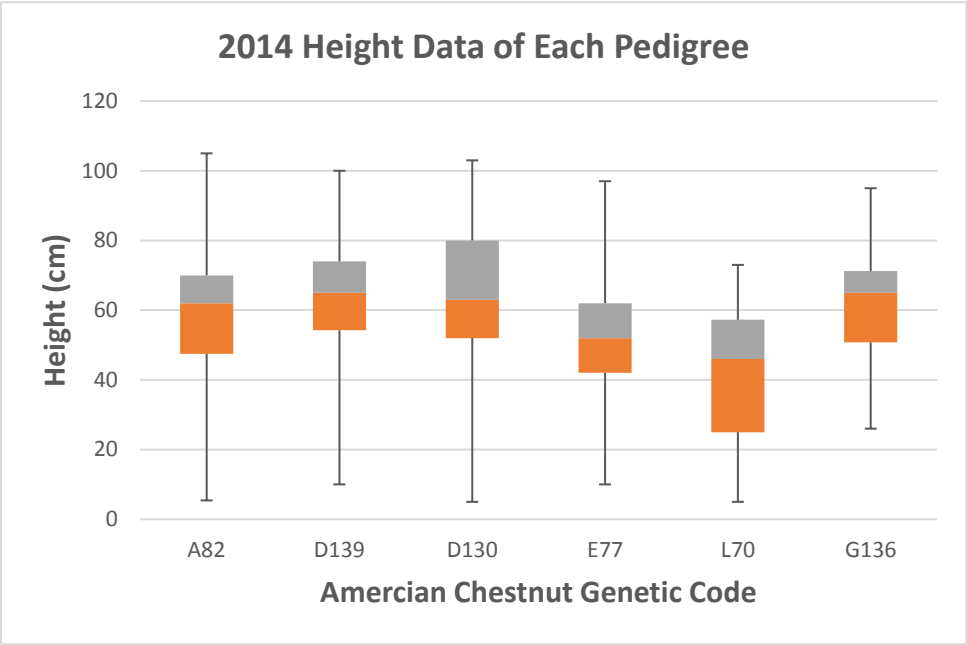


Figure 10: 2014 height data results.

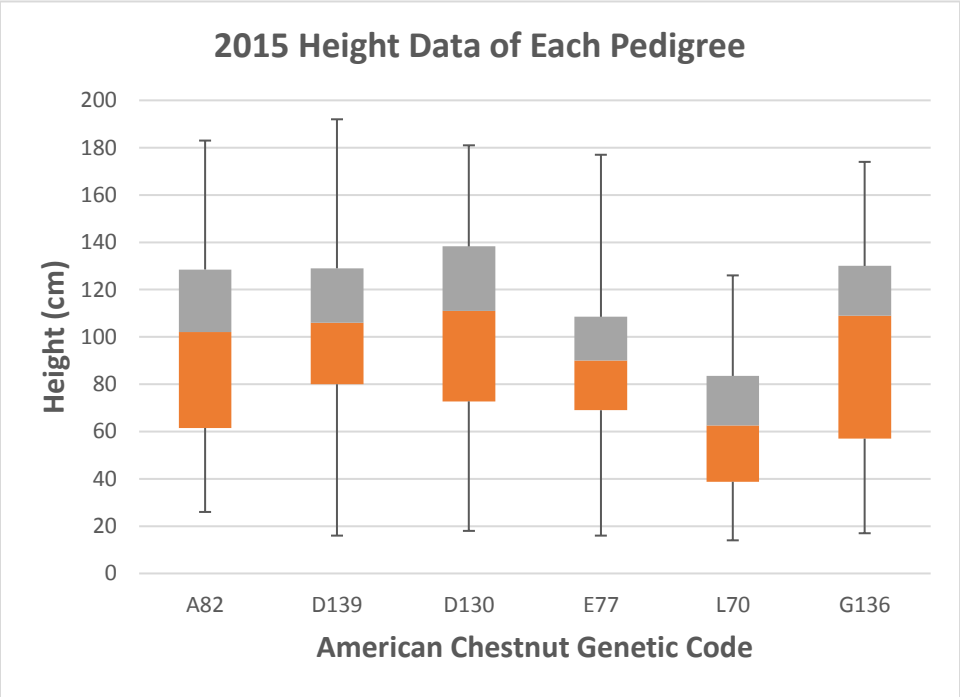


Figure 11: 2015 height data results.

high growth rate. I would eliminate L70 from the orchards because of its high mortality rate and lower growth rate. The true test of which breed of trees should be the recommended will be determined after they surpass eight years. Which one will survive the blight?

Conclusion

Forest land cover throughout the eastern United States has changed multiple times since the pre-colonial days. Deforestation due to logging and agriculture has been one reason. Once farmers left the fields vacant to explore the west, the grand American chestnuts and oaks became the predominant canopy in the east, reshaping land cover again. Then came the tragic blight of 1904 which practically wiped out the total American chestnut population. Most of what remained throughout the forests were stumps which sprouted future chestnut branches giving hope of restoration only to have most die from the blight again once they reached the flowering state. This cycle continues to this day. Hope is given to the researchers and scientists who have developed new seeds that may potentially be blight-resistant. Genetically modifying seeds and backcrossing through hand pollination and natural pollination are today's prospect of reviving the great "redwood of the east." Orchards of the purest modified American chestnut are young yet they show promise. Flowering has taken place and thousands of new seeds have been planted. Results from the next five to eight years will increase the confidence in these new breeds being blight-resistant. In the meantime the waiting brings questions over how the new hybrids will do.

Tom Kierauf, a retired forest researcher who helped plant 10,000 hybrid seedlings, is concerned because the chestnut trees evolved from fire. These trees became dependent on forest fires for regenerations. The fires opened up the understories enabling more light to come through for the seedlings that needed them (Middleton 2015). Will they be able to endure without the fires?

Once these new blight-resistant chestnuts grow, the forest will make a drastic change from floor to canopy. More shade will be provided to areas that have little. The decomposing leaves will provide more nutrients to the soil and water, and their trunks

will be a habitat to billions of insects and mammals. Their nuts will provide valuable nutrition to wildlife once again (Jabr 2014). How will this change the ecosystem?

Concern of ecological threat such as could genes flow from transgenic trees to sexually compatible wild trees? Tests are also made on the nutritional value of the nuts from these trees. Issues arise as to who will own, control and regulate the transgenic trees (Pinchot 2014)?

Anthropogenic causes bring concern for today's forest. Consumption of fossil fuels and deforestation are raising levels of fossil fuels which is causing atmospheric temperatures to increase and more frequent stormy weather. Will climate change impact and most likely alter the forests of Pennsylvania (Price et al. 2012)?

Though the Forest Health Initiative believes there is a blight-resistant transgenic American chestnut, the Center for Food Safety is concerned with the long-term consequences. This group often opposes the use of GMO's in agriculture. Decisions need to be made regarding whether to continue the genetic recovery of the American chestnut or wait for a natural recovery (Pinchot 2014). Ecosystems may be more dependent on humans for survival. More and more trees are becoming threatened. We have already lost most of our American chestnut and eastern hemlock. American beeches, oaks, black walnuts, elms, ashes, and flowering dogwood may also be relying on the genetic engineering.

These questions cannot be answered until the new breed of American chestnuts have changed the landscape of eastern United States again. The environmental benefits of the pre-blight chestnuts give hope that the recovered American chestnut will do the same. Pennsylvania alone has many impaired streams due to lack of riparian buffers along streams within agricultural areas. The fast-growing, carbon-sinking, nutrient-bearing American chestnut could be the remedy to Pennsylvania's problem.

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