Schlarbaum, S.E., S.L. Brosi, and S.L. Anagnostakis. 2005. Feasibility of large-scale reintroduction of chestnut to national park service lands: some thoughts. In, proc. of conf. on restoration of American chestnut to forest lands, Steiner, K.C. and J.E. Carlson (eds.).

FEASIBILITY OF LARGE-SCALE REINTRODUCTION OF CHESTNUT TO NATIONAL PARK SERVICE LANDS: SOME THOUGHTS

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Abstract: In the early 1900s, chestnut blight transformed the eastern deciduous forest by eliminating American chestnut as a dominant overstory species. Currently, reintroduction of American chestnut appears possible with blight-resistant chestnut hybrids soon becoming available from various breeding programs. Overcoming chestnut blight through integrating resistance from Chinese and Japanese chestnut into the American chestnut genome represents a crucial first step in the process of restoration. Successful reintroduction, however, requires consideration of site, seed source, seedling quality, and silvicultural requirements. In addition, there are other challenges in eastern forests that await resistant seedlings. Considerations for reintroduction procedures and potential problems are discussed.

Keywords: American chestnut / Chestnut blight / seedling establishment / reintroduction

INTRODUCTION

Reintroduction of blight-resistant chestnuts to eastern North American forests is one of the most anticipated events in natural sciences by the general public. Unique to chestnut is the formation of private nonprofit foundations whose mission is to develop planting stock resistant to the chestnut blight fungus [*Cryphonectria parasitica* (Murr.) Barr]. As predictions for the release of blight-resistant seeds and seedlings approach, attention should shift from blight resistance toward the ecological and silvicultural considerations that will also determine the success of reintroduction efforts. Detailed studies of forest ecosystems, e.g., Clements (1916), and North American forestry research (cf. Pinchot 1947) in general, were just occurring, as American chestnut [*Castanea dentata* (Marsh.) Borkh.] was being eradicated as an overstory species, so little is known about the establishment and growth of this species.

The feasibility of large-scale reintroduction of blight-resistant chestnuts requires a greater understanding of many factors. Aspects of chestnut establishment success include site selection, material selection, and anticipation of establishment challenges. Given the dearth of information on artificial regeneration of American chestnut, reintroduction strategy on National Park Service (NPS) lands should encompass existing information on establishment techniques on chestnut and closely relate genera, e.g., *Quercus* L., prior to or concurrent with the forthcoming release dates for hybrid material under the framework of existing natural resource management policy. This paper will consider some of the important factors that will affect reintroduction on NPS lands.

REINTRODUCTION CONSIDERATIONS

Site availability on National Park Service lands

Restoration of chestnut on federal and State land bases will be affected by land management policy for each respective agency. The forest is resilient in terms of response to disturbance, and the gaps left by dead chestnuts have long been filled by other species.   National Park Service lands are generally managed to mimic natural disturbance regimes, as opposed to USDA Forest Service lands that may be subjected to harvesting.   The first priority for reintroducing chestnut is to identify the appropriate sites for establishment.

American chestnut is an intolerant species and requires a yet-undetermined amount of light to grow and successfully compete in eastern forests. Opening sites for planting blight-resistant chestnuts through harvesting is not a viable option for National Park Service lands. On larger NPS lands, suitable sites for planting chestnut can become available through the effects of natural disasters, fire, and pests on forested land. Tornados, straight-line winds, and hurricanes all can cause forest destruction by blowing down or shattering trees, thereby opening sites. Depending on the severity, fire can remove the overstory and understory forest on significant acreages.   Natural and exotic pests can also create openings and gaps in which chestnut could be successfully established.

Seed Source Considerations

Conservation programs, aimed at increasing disease resistance can reduce genetic variation within the host species population. In the 1950s Forest Service breeding production programs for blister rust-resistant white pine in the western United States incorporated only 100 selected parent trees for reintroduction (Neuenschwander et al. 1999). The resulting seedlings, though disease-resistant, were limited in their 'fitness" or ability to adapt to varying environmental conditions (Buchert 1994). The natural geographic range and range of forest sites of American chestnut is large and therefore, individual breeding programs for different regions need to be implemented.

The use of seed sources adapted to local conditions is an important factor in artificial regeneration success (cf. Zobel and Talbert 1984).   When information about genetic variation and adaptability of the species are unknown, locally-adapted seed sources have proven to be importance for seedling survival and mast production (Wakeley 1963). Incorporating of locally-adapted genotypes into breeding programs is desirable, as the use of unproven genotypes can cause problems in:

- Short-term and long-term survival;
- Poor adaptability to local environment can mean poor productivity in terms of growth and frequency and quantity of mast production;
- Unproven genotypes could affect overall productivity of the forest through pollination of naturally occurring trees of the same species; and
- Planting of seedlings from unspecified seed sources could be challenged by private citizen, e.g., "environmentalist," groups

As National Park Service lands are managed as bioreserves, use of genotypes from the local gene pool in a breeding program is particularly desirable. Practicality, however, is another issue, as resources for separate breeding programs for each National Park Service land base is not feasible in the foreseeable future. Therefore, the critical question is, how far can seedlings of one breeding program be moved and still exhibit satisfactory survival and growth? In addition, there are significant environmental differences among chestnut sites within NPS lands with large acreages that can affect survival and growth.

In general, there are few guidelines for seed transfer in hardwood species (cf. Post et al. 2003) due to a relatively small amount of genetic testing done, in comparison to certain coniferous species. In the absence of these guidelines, identification of geographic areas with common environmental conditions, i.e., seed zones, can be useful to guide testing to determine seed transfer parameters. The wide range of physiographic and climatic conditions in Tennessee has lead to the creation of a hardwood seed-zone system as a guideline for seed collection throughout the state (Post et al. 2003). This system was developed using a Geographic Information System (GIS) and was based on elevation, Bailey's Ecoregions, 30 years of monthly precipitation, and 30 years of monthly minimum temperature data. Similar models can be created for large NPS land bases in combination smaller, proximal NPS land bases to guide seed transfer testing.

It is possible that these models may be further refined by using a geographic information system (GIS) analysis that incorporates site information from historic and current chestnut sites. Butternut (*Juglans cinerea* L.) is an eastern hardwood species that is being decimated by a disease caused by an exotic fungus (*Sirococcus clavigignenti-juglandacearum* Nair, Kostichka, & Kuntz). Over 80 percent of the butternut population in southern States has been destroyed (USDA Forest Service). Surveys for surviving butternuts in the Great Smoky Mountains National Park, Mammoth Cave National Park, and St. Francis National Forest have been aided by predictive models generated by GIS analyses (van Manen et al. 2002; Thompson et al. 2004a.b).

Seed Production

Seed orchards will be necessary to generate the copious amount of chestnuts needed for reintroduction on NPS lands. Placement of seed orchards should be carefully coordinated with the NPS lands that they are intended to serve. Unpredictable expression (or lack of expression) of certain traits have been known to occur in progenies from seed orchards that were located remote to the intended areas of reforestation (Skroppa and Johnson 2000). Development of seed orchard management protocols will be another area that will demand attention. Management protocols for American chestnut orchards can be guided by the large volume of experience and research on several *Castanea* Mill. species (J.H. Craddock, Pers. Comm., May 1, 2004).

Development of pest management schedules specific for chestnut seed orchards will probably be needed, as North American pests are different from European and Asian pest species. Post et al. (2001) studied the effects of insecticide spraying in a *Quercus rubra* L. seed orchard and found that a number of seed pests attack acorns. A variety of other pest species were also found in this orchard (Schlarbaum et al. 1998), which indicates that a significant amount of research will be needed to keep chestnut orchards healthy.

In general, the NPS does not have the necessary expertise, suitable land, nor equipment for seed orchard development and management. Successful seed orchards require expertise in tree improvement, genetics, forest pathology, and forest entomology and well as a technical staff that is trained for working in highly managed conditions. Seed orchards require pesticide spraying and fertilization, which are not usually conducted on NPS lands. The NPS also does not generally have the type of equipment needed for seed orchard management. As seed orchard development becomes more eminent, the NPS should consider cooperating with USDA Forest Service Regional Genetic Resources Programs and State Divisions of Forestry (or equivalent), which have trained personnel in seed orchard management, equipment, and the land with appropriate variances for insecticide spraying, etc.

Hardwood Seedling Quality and Establishment

American chestnut has been planted since the mid 1800s (cf. Emerson 1846). By the 1880s, experiments in establishing American chestnut on the Great Plains had been conducted for a number of years (Egleston 1884). Detailed studies of growth after establishment are lacking from these early years, as forestry research, indeed forestry itself, was in an infantile state in North American during the latter stages of the 19th century (cf. Pinchot 1947). Because of the lack of information regarding chestnut seedling establishment, it is advisable to adopt guidelines from comparable hardwood species in order to develop initial strategies to improve chestnut establishment. While survival rates and specific site and silvicultural requirements differ between oak species and chestnut, information on artificial regeneration of oak can provides useful information.

Establishment of seedlings from heavy-seeded hardwood species through natural or artificial processes in eastern hardwood forests is becoming increasing difficult in recent years. Invasions of sites by exotic plant and vine pests and a dramatic increase in white-tailed deer (*Odocoileus virginianus* Zimmerman) herds augment difficulties with suppression by faster growing light-seeded species and hardwood sprouts. Artificial regeneration protocols are needed to combat existing and growing challenges for successful establishment of blight-resistant seedlings on NPS lands.

Production of large, vigorous seedlings is a partial answer to these problems. Seedlings that are able to either maintain or grow sufficiently to keep the terminal bud/shoot above competition and above the level of deer browse will have an increased chance for survival and establishment. Nursery protocols developed by the USDA Forest Service's Institute of Forest Genetics and implemented by the Georgia Forestry Commission at the Flint River Nursery (Kormanik et al. 1993) have been shown to produce high quality 1-0 hardwood seedlings that are taller, thicker and have more robust root systems hardwood seedlings produced under standard nursery protocols. Studies with high-quality oak seedlings show a relative increase in establishment success (Kormanik et al. 2002). Chestnut establishment success will probably increase if seedling size is optimized.

Chestnut seedlings have responded favorably to protocols developed by Kormanik et al. (1993) at the Flint River Nursery and to an additional season of growth at in the northern Connecticut State Nursery. Some American chestnut seedlings (1-0) grown at the Flint State Nursery reached over 1.8 m in height, while some chestnut hybrid seedlings (2-0) were approaching 2 m tall at the end of a second growing season in Connecticut. There were genetic differences in nursery height, root collar diameter, and number of lateral roots among genetic families at both locations.

Plantings of the Georgia-gown seedlings in Kentucky incurred severe mortality and heavy competition (Brosi 2001). Mortality was primarily due to *Phytophthora cinnamomi* Rands., an exotic root rot disease brought into the country in the early 1800s (*teste* Clinton 1913) and chestnut blight, which had infected some seedlings in the nursery. Herbivory by deer also impacted the unprotected trees. Despite these problems and heavy competition from yellow-poplar (*Liriodendron tulipifera* L.), the surviving trees grew on average 40 cm a year. After two growing seasons, the seedlings had doubled their average initial height (average height: 106 cm in 2000, 203 cm in 2002, and 224 cm in 2003). Three growing seasons after outplanting some seedlings reach almost 4 m tall and were competing with yellow-poplar sprouts and seedlings.

Plantings of the Connecticut-grown seedlings in Connecticut incurred little mortality. Competition was restricted with the use of herbicides and hand-cutting, and the trees were protected from herbivory with plastic mesh tree shelters. The seedlings (from hand-pollinated crosses) were second-backcross Japanese (*Castanea crenata* Sieb. & Zucc.) hybrids crossed with two different American Chestnuts, and first-backcross Chinese (*Castanea mollissima* Blume) hybrids crossed with the same two Americans. Growth was best in three forest clearcuts, and was poor in an old field. Japanese hybrids averaged 258 and 225 cm height after three seasons in clearcuts and Chinese hybrids averaged 216 and 227 cm. In the old field Japanese hybrids averaged 213 and 119 cm and Chinese hybrids averaged 155 and 188 cm after three seasons.

There were differences in seedling growth across nitrogen content in two planting locations indicating chestnut's ability to respond to soil differences in both Connecticut and Kentucky. Chestnut is often considered a species that can grow across a wide range of nutrient conditions given its historical range.

Delineating nutritional factors that influence chestnut growth will provide better information for site selection in chestnut restoration and will allow for appropriate fertilization of seedlings to augment growth. Further investigations are needed into different soil conditions and nutrient amendments to determine their interactions with initial seedling growth.

ADDITIONAL CHALLENGES AFTER RESTORATION

Production of blight-resistant, timber-type chestnuts is an important milestone in the restoration of this genus to eastern North American forests. Resistance to chestnut blight disease is, however, only the first step toward restoration. There will probably be other challenges to chestnut throughout its life cycle from both native and exotic organisms. Indigenous pests such as the two-lined chestnut borer could emerge as serious problems, depending on the density and vigor of the restored species. Chestnut blight disease is just one of the serious exotic problems that planted chestnuts will face. Below is a list of some of the most serious exotic pests that may affect the plantings.

Phytophthora cinnamomi

Historically, mortality of American chestnut and Allegheny and Ozark chinkapins (*Castanea pumila* Mill. and *C. ozarkensis* Ashe., respectively) from root rot disease caused by *Phytophthora cinnamomi* is second only to chestnut blight disease. As mentioned above, the disease entered the country in Georgia during the early 1800s and rapidly spread. By 1878, American chestnuts in North Carolina River basins were noted to be dying (Hough 1878). American chestnuts and chinkapins were essentially eliminated from wet, poorly-drained soils and soils with heavy clay content by the turn of the 20th century (Crandall et al. 1945). Site selection is often considered the most important factor in reducing losses due to *Phytophthora* (Agrios 1997; Campbell and Copeland 1954) and will be an important consideration in planting blight-resistant chestnut.

Chestnut Gall Wasp (*Dryocosmus kuriphilus* Yasumatsu)

This insect was accidentally imported into the United States on smuggled budwood of Japanese chestnut, (Payne et al. 1975). The pest lays eggs in vegetative and floral buds, and feeding by larvae forms galls. Branch dieback can occur, and severe infestations can cause mortality. The range of chestnut gall wasp is still expanding north and west in eastern North America.

Exotic Ambrosia Beetle (*Xylosandrus crassiusulus* Mot. and *Xylosandrus saxeseni* Blandford)

These introduced insects have been found to infest chestnut seedlings and grafts in field and forest plantings and can cause mortality (Oliver and Mannion 2001). Other ambrosia beetle species have been recently imported into the eastern United States and could potentially cause problems for juvenile and adult chestnuts (Campbell and Schlarbaum 2002).

European Gypsy Moth (*Lymantria dispar* L.)

European gypsy moth will feed on American chestnut, but it is not a preferred species.

Sudden Oak Death (*Phytophthora ramorum* Werres et al.)

Sudden Oak Death was first detected in California coastal forests in 1995 (Werres et al. 2001), and has since progressed into Oregon forests. The disease causes mortality in a number of hardwood species, including *Quercus* and *Lithocarpus*, which are in the same family (Fagaceae) as *Castanea*. *Phytophthora* *ramorum* has a wide host range and occurs on rhododendrons and other species grown by the nursery industry. USDA APHIS did not initiate interstate restrictions on movement until 2002. Currently, it has been discovered in 14 other States including a number of eastern states on nursery stock exported from California and Oregon (F.T. Campbell, Pers. Comm., June 3, 2004). Tests have confirmed that European chestnut is susceptible to *Phytophthora ramorum* (Defra, 2004). Although this pathogen has been brought to eastern states on nursery stock, confirmation of infestation in natural or urban trees has yet to be reported. In addition to these species, the number of exotic pests is likely to increase in the forthcoming years due to trade agreements and treaties that fail to adequately protect the United States from new threats (Campbell and Schlarbaum 2002).

CONCLUTIONS

The above text has elucidated some of the factors that will contribute to or challenge the successful restoration of chestnut. Although it may be a number of years before significant numbers of blight-resistant seedlings are available, much information can be gathered by planting pure American chestnut or advanced generation hybrid chestnuts. Chestnut blight disease does not necessarily infect and kill young seedlings upon outplanting. Seedlings can maintain good health and growth for a number of years and thereby, contribute to the understanding of the silvics of the species. Plantings of advanced generation hybrid chestnuts on NPS lands can always be cut down after their study objectives are fulfilled. Concerns about pollen/seed contamination into existing American chestnut gene pools on NPS lands are negligible, as Asian germplasm is not competitive in eastern forests (Schlarbaum et al. 1994). Such plantings also can provide a better understanding of sites likely to have *Phytophthora cinnamomi*, which will be key to future successful chestnut plantings.

ACKNOWLEDGEMENTS

Special thanks to the many cooperators who have helped make this research possible including: Paul Kormanik (USDA Forest Service's Institute of Forest Genetics); Tom Tibbs (retired USDA Forest Service); The Georgia Forestry Commission; Chuck Rhoades; Paul Vincelli (University of Kentucky); Fred Hebard and Paul Sisco (The American Chestnut Foundation); Mark DePoy and Brice Leech Jr. (Mammoth Cave National Park); Tom Hall (Pennsylvania Bureau of Forestry); John Perry (Berea College Forest); Jeff Lewis (Morehead Ranger District of the Daniel Boone National Forest); Pamela Sletten (The Connecticut Agricultural Experiment Station) and Tree Improvement Program personnel (The University of Tennessee, Knoxville).

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