Evaluation of Experimental Chestnut Plantings in Eastern North America

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ABSTRACT. Evaluations were made of chestnut plantations that were established over the last six decades in eastern North America. The plantings contain a variety of experimental materials, ranging from pure *Castanea* spp. to complex *Castanea* hybrids. Observations were made on survival, form and vigor in all plantations. Height and diameter growth were measured in selected tests. Survival was found to be poor, ca. < 20 percent, in most plantings. Height growth was generally found to be less variable than diameter growth. Cultural management practices appear to be important in plantation growth and survival. Trees were selected for eventual incorporation into chestnut breeding and disease research programs. Several plantings were identified that could be converted to seedling seed orchards for reforestation purposes.

The destruction of American chestnut, *Castanea dentata* (Marsh.) Borkh., by the chestnut blight fungus, *Cryphonectria parasitica* (Murr.) Barr, spawned numerous research programs to return or maintain a chestnut component in eastern North American forests (6). The discovery of blight resistance in Asian chestnut species was responsible for the initiation of breeding programs by state and federal agencies (1, 3, 6) and an increase in collection and introduction of foreign *Castanea* germplasm (5). Breeding programs were conducted at various institutions including the Brooklyn Botanical Gardens, Connecticut Agricultural Experiment Station, and Bureau of Plant Industry, United States Department of Agriculture (USDA). These programs made intraspecific and interspecific cross pollination using different *Castanea* species and accessions. The longevity of certain breeding programs made it possible to generate complex hybrids, e.g., *(C. mollissima* Bl. x *C. dentata) x C. dentata* for evaluation (3). The seed collections of exotic chestnut species were made primarily in China and Japan; the imported seedlots were assigned plant introduction numbers. Different accessions of Asian chestnut species, usually *C. mollissima* and *C. crenata* Sieb. and Zucc., were directly planted in field tests or used to establish seed orchards for production of experimental materials.

Castanea field tests have been established over the past six decades using materials produced by breeding and introduction programs (7). Two major test series, the "Asian Chestnut Climatic Tests" and the "Hybrid Chestnut Tests" were planted into different habitats in eastern North America. Evaluations of these experiments, however, have been sporadic. The latest published report on the "Asiatic Chestnut Climatic Tests" was by Diller and Clapper in 1969 (7). Berry reexamined the fifteen "Hybrid Chestnut Tests" in 1978 (2). No other reports on a collective evaluation of either study has been published since Berry's paper.

In addition to the above test series, numerous other chestnut plantations have been established, either for research purposes or as reforestation plantings. Generally, these miscellaneous plantings have had no evaluation or only a cursory, unpublished examination.

The potential exists for selection of valuable materials from existing chestnut plantations for use in current breeding and disease research programs (3, 8). This prompted an effort to ascertain the status of plantings in the "Asiatic Chestnut Climatic Tests" and "Hybrid Chestnut Tests" series. During 1992, certain plantations from these studies and miscellaneous chestnut plantings were visited to evaluate survival, form, vigor, growth and growing conditions.

MATERIALS AND METHODS

"Asiatic chestnut climatic tests." Twenty-one plantations were established during the period from 1936-1939 by the USDA and cooperators in various states; the tests were planted in different plant growth regions. Overall, the study contained approximately 22,000 trees, representing a combination of 25 Asian accessions, species and hybrids. The objective of the study was to evaluate the experimental materials for blight resistance and adaptability in different North American environments. Two tests were almost immediately destroyed after planting, by a railroad relocation and deer, leaving 19 plantations at 13 locations (Figure 1). Four plantations were evaluated in the present study (Figure 1; Table 1).

"Hybrid chestnut tests." Experimental materials from USDA, Connecticut Agricultural Experiment Station and other breeding programs were assembled by Diller, Clapper, and Graves and planted in 15 tests at 14 locations (Figure 2). The plantations were established from 1946 to 1955 and contained 12,250 hybrids and 541 *C. mollissima* (PI 58602 open-pollinated) seedlings. The studies were planted to evaluate the field performance and blight resistance of hybrid chestnuts and to compare hybrid performance with C. *mollissima* seedlings from an accession that had shown good blight resistance and adaptability in previous studies. Six plantations were evaluated in the present study; five tests in 1992 and the Norris, Tenn. test in 1989 (Figure 2; Table 1).

Figure 1. Locations of the "Asiatic Chestnut Climatic Tests." Numbers indicate plantings evaluated in this study (Table 1). Shaded circles indicate plantings not evaluated.

Figure 2. Locations of "Hybrid Chestnut Tests." Numbers indicate plantings evaluated in this study (Table 1). Shaded circles indicate plantings not evaluated.

Figure 3. Locations of miscellaneous chestnut tests evaluated in this study (Table 1).

Miscellaneous chestnut plantations. During the consultations with local cooperators to coordinate inspection of the above plantations, the existence of other chestnut plantings in proximal areas was frequently mentioned. These plantations were established at different ages and contained materials from various or unknown origins. As the plantings were often in the vicinity of the above tests, they were evaluated for trees that could be integrated into breeding programs (Figure 3, Table 1).

Evaluation procedures. The large distances between experimental plantings and lack of sufficient resources dictated different degrees of evaluation for each plantation. All studies were evaluated for survival, form, and general vigor. The form was considered to be timber-type if the trunk was essentially a single stem. Observations on the present and past (if possible) growing conditions and cultural management activities at each site were made. Growth measurements were made using a diameter measuring tape (at 1.4 m) and clinometer. Means and standard deviations were calculated from the measurements. Table 1 indicates the growth measurements that were taken at each plantation.

RESULTS

"Asiatic chestnut climatic tests." The Virginia plantation in the George Washington National Forest had the best survival (2.7%) of the tests evaluated from this study (Table 1). The trees are part of the overstory and competing well with the surrounding forest. According to Forest Service records, the plantation was thinned in 1963 and had been fenced at some time. Growth was measured in a representative sample of the trees. Diameters ranged from 25-35 cm, and heights were between 15-20 m. Injury from blight was observed in varying degrees, and large, dead trees were present. Some trees had a timber form, i.e., single trunk.

The planting in the Pisgah National Forest, North Carolina had lower survival than the Virginia plantation (1.5%), but the trees appeared to be more vigorous. The plantation suffered from cattle grazing in the first year after establishment, but was fenced to prevent further damage (J.D. Diller, USDA internal work plan). Invading hardwoods are virtually absent from the site, and there is evidence that a relatively recent fire may have removed the groundcover. A number of trees have a timber form, and several have attained a relatively large size (Table 1). Some trees have serious blight damage and are noticeably less vigorous in appearance.

The Pennsylvania plantation and the Sumter National Forest plantings, in South Carolina, had no survival. Diller and Clapper regarded the Pennsylvania planting to be viable in 1969, but rated the South Carolina planting as unsuccessful. Local Forest Service personnel at the Sumter National Forest had observed ten trees surviving at some time in the past. These trees apparently succumbed in the succeeding years to invading vegetation. The Pennsylvania planting was on a site considered to be optimal for American chestnut, and contained 4 trees considered to be

Table 1. Survival, diameter and height statistics for observed chestnut plantations.

	Survival				Diameter				Height			
Plantation type/location	Date Established	# Planted	# Living	% Survival	Min.	Max.	Mean	SD	Min.	Max.	Mean	SD
Asiatic chestnut climatic tests												
George Washington National Forest Pedlar District, Buena Vista, Va.	1936	1350	36	2.7	–	–	–	–	–	–	–	–
Pisgah National Forest, Toecane District, Burnsville, N.C.	1936	1350	20	1.5	14.0	44.0	25.6	8.90	17.0	28.0	22.5	3.48
Michaux State Forest, Wayneboro, Pa.	1938	1350	0	0	–	–	–	–	–	–	–	–
Sumter National Forest, Tyger District, Union, S.C.	1939	714	0	0	–	–	–	–	–	–	–	–
Hybrid chestnut tests												
Prunytown State Farm, Grafton, W.Va.	1953	150	12	8.0	15.0	32.0	23.5	1.04	9.0	25.0	20.7	5.12
Table Rock State Park, S.C.	1948	124	23	18.5	16.5	48.0	28.0	7.46	15.0	26.0	21.0	2.93
Crab Orchard National Wildlife Refuge, Centerville, Ill.	1949	100	6	6.0	26.0	42.0	33.8	6.82	18.0	22.0	20.0	1.58
Nathan Hale Farm A, Coventry, Conn.	1953	90	35	38.9	2.5	40.1	20.8	8.73	–	–	–	–
Nathan Hale Farm B, Coventry, Conn.	1953	98	36	36.7	0.3	33.8	19.8	7.26	–	–	–	–
Tennessee Valley Authority, Norris, Tenn.	1947	128	13*	10.2*	–	–	–	–	–	–	–	–
Miscellaneous chestnut planting												
Jefferson National Forest, Wise, Va.	unk.	unk.	43	–	15.0	40.0	26.7	6.87	–	–	–	–
Cumberland State Park, Cumberland, Va.	1951	98	4	4.1	16.0	19.5	17.6	1.49	15.0	19.5	16.4	2.14
Bent Creek Experimental Forest, Asheville, N.C.	1953	–	–	–	–	–	–	–	–	–	–	–
Sumter National Forest, Whitmire, S.C.	unk.	–	–	–	–	–	–	–	–	–	–	–
Tennessee Valley Authority, Norris, Tenn.	1949–50	198	130	65.7	12.5**	107.0**	52.9**	18.95**	–	–	–	–

*Evaluated in 1989
**Basal diameter

"promising" by Diller and Clapper. Gypsy moth infestations may have had been a contributing factor to this plantation's demise.

"Hybrid chestnut tests." The West Virginia plantation contained 12 (8.0%) surviving trees and several sprouts. The trees are part of the canopy, and the plantation has been invaded by hardwoods that are approximately the same height as the chestnuts. The plantation is now surrounded by agricultural fields. One tree exhibited good height growth (25 m) and another tree had relatively good diameter growth (32 cm) (Table 1). Only three trees had identification tags. All trees were timber form. Blight damage was evident on some trees, with a number of dead trees still standing.

The hybrid chestnut plantation at Table Rock State Park in South Carolina had 23 (18.5%) surviving trees, with 15 identification tag still present (Table 1). The plantation is in a clearing, and the trees are in the forest canopy. However, the surrounding forest is beginning to encroach upon the test and is affecting the growth of trees on the plantation's perimeter. The plantation is free from invading hardwoods and is mowed. All trees were timber form and were generally the most vigorous observed in the hybrid test series. Blight infection is present on some trees, and there are standing dead trees.

The Illinois planting in the Crab Orchard National Wildlife refuge was best known because it contained the Clapper hybrid, a product of a *C. mollissima* × *C. dentata* hybrid backcrossed to *C. dentata* (4, 11). This tree had excellent growth and form, but finally died from blight infection (3). Six trees (6.0%) were found to be surviving, and all showed damage from chestnut blight. Hardwoods have invaded the site, although the chestnuts are still in the canopy. The surrounding forest is beginning to compete with the plantation. Several trees have large diameters, but lacked timber form and relatively good height growth (Table 1).

Two hybrid chestnut plantations were established at the Nathan Hale Farm in Connecticut. Both plantings had excellent survival (Table 1), and all trees can be identified.

The mean diameter of the Nathan Hale A planting was slightly larger than the Nathan Hale B planting. Trees with timber form were present in both plantations.

The hybrid chestnut planting at Norris, Tenn. was not located for evaluation in 1992. The plantation area had been thinned in the late 1980's to improve timber quality and is presently covered in dense undergrowth. Survival in this plantation was evaluated in 1989 and found to be 10.2 percent (13 trees). Of the remaining trees, 10 were living and 3 had been cut inadvertently in management activities. Unfortunately, the largest tree in the plantation was among the cut trees.

Miscellaneous chestnut plantations. A *C. mollissima* plantation in the Jefferson National Forest, near Wise, Va., was inspected for timber form trees. The origin and exact age of the plantation are unknown, although local Forest Service personnel believe it was planted in the early 1960's. The planting consists of 43 trees and appears to have been infrequently maintained by mowing or clearing of saplings. **No** timber form trees were present, although some trees exhibited good diameter growth and mast production (Table 1). Some trees were infected with blight.

Two *C. mollissima* plantations were evaluated at Cumberland State Park in Virginia. The plantations were established in 1951 with materials received from the USDA Bureau of Plant Industry, but no accession number can be found in the plantation's documentation. Four trees have survived, but are currently in the understory. One tree had a timber form and no evidence of chestnut blight.

A chestnut plantation in the Bent Creek Experimental Forest (U.S. Forest Service), near Asheville, N.C. was found to be part of an unknown chestnut test series. The planting is one of three plantings established in 1953 byJ.D. Diller as the "Chestnut Strains Tests." The plantings contain *C. mollissima* seedlings from what Diller refers to as "promising" accessions. Two plots were established at Bent Creek. Mortality was heavy in one plot that was dominated by a low area. The other planting was on a hillside and exhibited good survival and growth. A high percentage of the trees have timber form. In consideration of the other plantings evaluated in 1992, this planting contains the highest percentage of desirable trees for integration into a breeding program. No measurements were made, as the planting will be measured in conjunction with sister plantations, if possible.

Three *C. mollissima* plantations were inspected in the Sumter National Forest, near Whitmire, S.C. Two plantations apparently were established from Forest Protection accessions, FP721 and FP723, at an unknown date. Three trees have survived, but are heavily infected with chestnut blight. A large plantation (4 + hectares) was established in 1970, but is being outgrown rapidly by invading pines and hardwoods. No trees were observed with timber form.

Chestnuts growing in a Tennessee Valley Authority plantation of exotic tree species near Norris, Tenn. were evaluated for form and basal diameter. The plantation contains chestnut species, hybrids and accessions, and was established in multiple years (1940, 1942, 1948 and 1959). Basal diameter measurements were necessary, as the majority of trees had forked below 1.4 m. The measurements showed a wide range in basal diameter (Table 1). Only one tree had good timber form and exhibited no evidence of blight infection.

DISCUSSION

Mortality has been high in the majority of the "Asiatic Chestnut Climatic Tests" and the "Hybrid Chestnut Tests." Standing dead trees and trees with reduced vigor indicate that the plantations have not quite stabilized in terms of blight resistance and adaptability. Nevertheless, there are individual trees that have good growth, form, blight resistance and adaptability. These trees can be grafted and integrated into existing breeding programs. Additionally, trees identified as resistant to blight infection can be utilized in disease and breeding research programs as comparative standards.

Survival appears to be affected by plantation management or cultural conditions. The hybrid chestnut plantings with the highest survival percentages, Table Rock State Park (18.5%) and the two Nathan Hale plantations (38.9% and 36.7%), had relatively little competition. The Table Rock State Park planting has been mowed and the Nathan Hale plantings grow in an environment that does not promote establishment of aggressive invasion species. The high survival (65.7%) in the miscellaneous chestnut planting at Norris, Tenn. also supports this hypothesis. This plantation received continuous maintenance from 1940 through the early 1960's.

Inspection of the growth measurements' standard deviations in Table 1 reveals some interesting trends. In the plantations where diameters were measured, the standard deviations are large with several exceptions. Standard deviations of heights, with one exception are generally lower. Although more data is needed, this may indicate that height growth is slowing as age progresses, while diameter growth continues to be variable. This pattern appears to be present irrespective of plantation location. A possible reason for this trend is the prevalence of pure Asian chestnut species and hybrid chestnuts, with an Asian species-dominated pedigree, in the different plantings. The height growth potential of Asian species is more limited than *C. dentata,* and the trees may have reached their potential limit in height growth at a comparatively young age, i.e. 40-50 years of age. Correspondingly, the height differences among trees at a particular site would gradually diminish; hence the lower standard deviation values.

The continued survival of trees that are pure Asian chestnut species or hybrids with a large Asian component suggests that an Asian species-based breeding and/or propagation program is warranted. Many North American chestnut breeding/testing programs have been concentrating on producing an American chestnut with blight resistance that will live in a forest setting. Although it is evident that Asian species and hybrids cannot replace *C. dentata* with respect to timber production, they can be a suitable substitute for mast production. Use of Asian chestnuts for

this purpose was mentioned by Jaynes (9, 10) and others (12, 13), but has been essentially ignored. Current trends in forest management are emphasizing a multiple use concept that includes both plant and animal management. Planting of Asian chestnut species/hybrids that are propagated from materials proven for blight resistance and adaptability in long-term field tests could greatly aid wildlife management objectives in forested areas. The U.S. Forest Service is presently considering conversion of the "Asiatic Chestnut Climatic Tests" on the George Washington and Pisgah National Forests to seedling seed orchards. With proper management, these orchards would produce chestnut seedlings that are adapted, blight resistant, and competitive in eastern North American forests.

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