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COOPERATIVE TEST PLOTS PRODUCE SOME PROMISING CHINESE AND HYBRID CHESTNUT TREES

In attempts to find a chestnut tree that is resistant to the blight fungus *Endothia parasitica,* Asiatic chestnuts have been imported and grown in this country, and tree breeders have worked to produce hybrid trees that might be suitable substitutes for the blight-susceptible American chestnut, *Castanea dentata,* in timber and nut production.

These efforts during the past 30 years have produced a number of hybrid trees; and one Chinese chestnut from Nanking (accession number PI-58602) has proved to be superior in blight resistance, tree form, growth rate, and nut production. To compare the hybrid trees with this Chinese chestnut, 15 cooperative test plots were established by the senior author. The plots were on private, state, and Federal land.[1]

Two plots were established in the spring of 1947 in Connecticut (Litchfield County), and Tennessee. Subsequently, plots were established in Alabama, Arkansas, Connecticut (Tolland County), Illinois, Michigan, Missouri, New Hampshire, New York, Ohio, Pennsylvania, South Carolina, and West Virginia. A total of 1,746 trees were planted: 500 hybrids from Glenn Dale, Md.; 705 hybrids from Hamden, Conn.; and 541 Chinese trees from Glenn Dale.

[1] The authors thank the many institutions and agencies on whose lands the 15 cooperative plots were established. And they gratefully acknowledge the splendid cooperation and assistance given by the many field cooperators in preparing and maintaining the test sites and in collecting data over the years.

The Glenn Dale hybrids were developed by Russell B. Clapper and his associates in the U. S. Department of Agriculture's Division of Forest Pathology. The Connecticut hybrids were developed by the late Arthur H. Graves and his colleagues, first at the Brooklyn Botanic Garden and later (1947-62) at the Connecticut Agricultural Experiment Station. The Chinese chestnut seedlings, also grown at the Glenn Dale nursery, were PI-58602 and a few replants of Chinese chestnut 55984 from Yunan Province.

Table 1.—*Location and planting detail of 15 chestnut-tree plots*

Plot No.	Location	State	County	Established	Trees planted			
					Hybrids		Chinese	Total
					Hamden	Glenn Dale	Glenn Dale	
				Year	*No.*	*No.*	*No.*	*No.*
1	Great Mountain Forest	Conn.	Litchfield	1947	50	23	58	131
2	Norris Dam, TVA	Tenn.	Anderson	1947	51	22	55	128
3	Antioch College	Ohio	Greene	1948	25	37	17	79
4	Table Rock State Park	S. C.	Pickens	1948	66	19	34	119
5	National Wildlife Refuge	Ill.	Williamson	1949	25	49	25	99
6	County Recreation Park	Pa.	Montgomery	1949	25	49	25	99
7	Russ Forest	Mich.	Cass	1951	50	39	13	102
8	Nathan Hale Farm (A)	Conn.	Tolland	1951	42	0	48	90
9	Nathan Hale Farm (B)	Conn.	Tolland	1951	49	0	49	98
10	Ouachita National Forest	Ark.	Polk	1952	58	30	20	108
11	Boys' Industrial School	W. Va.	Taylor	1953	50	49	50	149
12	Guntersville Dam, TVA	Ala.	Marshall	1954	50	50	50	150
13	State College of Forestry	N. Y.	Onondaga	1954	50	49	51	150
14	Sinkin Experimental Forest	Mo.	Dent	1954*	64	34	46	144
15	Abbott State Forest	N. H.	Hillsboro	1955	50	50	0	100
	Total	—	—	—	705	500	541	1,746

*All plots were planted in the spring except the plot in Missouri, which was planted in December.

Methods

At each location the trees were planted on forest land of above-average hardwood site quality. These were sites where various plant indicators suggested that chestnut might do well. These sites were characterized by deep, fertile, and well-drained soils with a covering of leaf litter and humus (Diller 1950).

One fairly reliable plant indicator, common to most of the areas, was yellow-poplar (*Liriodendron tulipifera*). Accordingly, the planting sites were chosen where yellow-poplars either were already established or might be expected to make good growth.

Before planting, all native overstory trees 2 inches d.b.h. and larger were girdled. In most plots saplings less than 2 inches d.b.h. were left standing. Subsequent maintenance was necessary on all the plots. In one Ohio plot all volunteer woody vegetation was cut back to the ground. On a few sites, herbaceous vegetation and some of the lesser woody species invaded the area and suppressed the planted trees.

Table 1 gives the location and planting detail for each plot. Originally it was hoped that 150 trees could be planted in each plot — 50 hybrids each from the Connecticut and the Maryland sources, and 50 Chinese chestnuts from Maryland. But because some hybrid chestnut seedlings were damaged at the nurseries the total number of trees planted per plot varied from 79 to 150.

Connecticut plots A and B did not receive any Glenn Dale hybrids, and the New Hampshire plot did not receive any Glenn Dale Chinese. All other plots were planted with the Hamden and Glenn Dale hybrids, and the Glenn Dale Chinese in varying numbers.

All the plots were planted in the spring except the Missouri plot, which was planted in early winter. The trees were planted randomly at a spacing of 10 x 10 feet.

In August and September 1963 the 15 plots were inspected and the 20 to 25 most promising trees in each plot were measured for height and d.b.h. Because of differences in site, year of establishment, and the diverse genetic constitution of the hybrids, it was impossible to make a formal statistical analysis of the growth measurements.

Results

All the trees that had averaged at least 2 feet in height growth per year are listed in table 2, along with their source, age, and pedigree. The 67 trees that met this requirement represented about 4 percent of

Table 2.—*Chestnut trees in test plots that averaged at least 2 feet height growth per year*

Connecticut hybrids						Glenn Dale Chinese						Glenn Dale hybrids				
Plot	Code No.	Age*	Pedigree	D.b.h.	Ht.	Plot	Code No.	Age*	Pedigree	D.b.h.	Ht.	Plot	Code No.	Age*	Pedigree	D.b.h.	Ht.
		Years		*In.*	*Ft.*			*Years*		*In.*	*Ft.*			*Years*		*In.*	*Ft.*
Conn.	40	18	JAxOP	5.9	37	S. C.	F67	17	58602	6.6	40	S. C.	F31	17	CxCJ	6.3	35
Tenn.	252	18	JAxOP	3.8	37	S. C.	F26	17	"	4.9	35	S. C.	F21	17	AhOP	6.2	40
Pa.	E51	16	CxJ.JA	4.4	35	S. C.	F84	17	"	4.8	37	S. C.	F22	17	AhOP	5.0	40
Pa.	E56	16	CxJ.JA	4.1	35	Pa.	F14	16	"	4.1	33	S. C.	F36	17	AhOP	4.5	37
Ill.	B79	16	ACxJC	4.5	32	Ill.	B59	16	"	5.3	40	Pa.	E40	16	AOP	5.4	37
Ill.	B22	16	J.CA	3.0	32	Ill.	B69	16	"	4.7	33	Pa.	E44	16	—	3.9	35
Conn. (A)	11-4	14	AxC.JA	3.8	31	Ill.	B70	16	"	3.8	36	Pa.	E87	16	CxC	4.7	35
Conn. (A)	14-2	14	ACxC	2.9	29	Ill.	B1	16	55984	3.3	33	Pa.	F2	16	CxC	4.1	33
Conn. (B)	12-2	14	J.JAxC	3.7	35	Conn. (B)	1-2	14	58602	3.5	33	Ill.	B26***	16	CAxA	7.3	45
Ark.	64	13	C**	4.0	37	Conn. (B)	3-5	14	"	3.4	33	Ill.	B56	16	CxH	5.3	37
Ark.	37	13	CxJA**	4.0	28	Conn. (B)	5-2	14	"	3.3	33	Ill.	B23	16	CAxC	2.9	33
Ark.	82	13	CxJA**	3.4	26	Conn. (B)	4-5	14	"	3.2	31	W. Va.	80	12	CAxC	2.6	26
Ark.	21	13	C**	3.5	26	Conn. (B)	1-4	14	"	2.9	30	W. Va.	79	12	CAxH	2.5	26
Ark.	36	13	CxJA**	3.1	28	Conn. (B)	4-7	14	"	2.9	28	W. Va.	148	12	CAxC	2.5	30
W. Va.	78	12	AxC.JA	4.3	32	Conn. (B)	5-5	14	"	2.2	30	W. Va.	147	12	CAxC	2.1	24
W. Va.	125	12	AxC.JA	3.4	32	Ark.	44	13	"	3.3	26	W. Va.	19	12	CAxC	2.0	24
W. Va.	74	12	JAxC	3.3	28	W. Va.	9	12	"	3.4	38	Ala.	31	11	CxC	3.3	27
W. Va.	8	12	C.JAxC.JA	1.9	26	W. Va.	15	12	"	3.3	34	Ala.	52	11	CxC	2.5	24
W. Va.	127	12	JAxC	2.2	24	W. Va.	45	12	"	3.3	30	Mo.	59	10	CAxCA	2.4	21
W. Va.	144	12	JAxC	2.3	24	W. Va.	16	12	"	3.0	38						
Mo.	150	10	JAxC	2.0	21	W. Va.	135	12	"	3.0	28						
						W. Va.	14	12	"	2.6	32						
						W. Va.	47	12	"	2.5	26						
						W. Va.	43	12	"	2.3	28						
						W. Va.	73	12	"	2.3	28						
						Ala.	45	11	"	3.0	23						
						Mo.	38	10	"	1.9	21						

*Trees were 1-3 years old when planted. Age is given as number of growing seasons on plot plus 1.
**Grafted trees. All on Chinese rootstock except Ark 64, which is a Chinese on Japanese rootstock. A = American, *Castanea denta;* C = Chinese, *C. mollissima;* J = Japanese, *C. crenata;* H = Henry, *C. henryi;* h = hybrid; OP = open-pollinated.
***Most outstanding hybrid tested.

the original number planted in the 15 plots. No trees in Michigan, New Hampshire, New York, and Ohio plots grew this well. The arbitrary height-growth yearly increment failed to furnish clues to the more important limiting factors for the poorer plots.

By far the most outstanding hybrid tested, tree B26, is located in the Illinois plot. It measured 7.3 inches d.b.h. and 45 feet in height — an annual growth of 0.43 inches d.b.h. and 2.6 feet height — in 17 growing seasons from seed (Clapper 1963). This tree has recently been named *Clapper chestnut* by Little and Diller (1964).

The pedigrees of the hybrids listed in table 2 are for the hybrids planted originally. Most trees that were highly susceptible to the blight fungus succumbed within 4 or 5 years. But by no means have all the susceptible trees been killed. For instance, many other miscellaneous plantings in which the Connecticut hybrid A x C.JA was represented became infected and were killed by the blight; so it can be predicted that some of the Connecticut hybrids of similar pedigree also will become blighted.

Grafted chestnut trees from Connecticut, planted in the Arkansas plot, have done well. Two of the trees, Ark 37 and Ark 36, are grafts of two hybrids recently described by Jaynes and Graves (1963) as C2 (Sleeping Giant chestnut) and C4. Both trees were grafted on Chinese rootstock. The surprisingly unexpected increased height (and d.b.h.) increment, which resulted when hybrid chestnut scions were grafted onto certain Chinese chestnuts as rootstocks, was not discovered until the Arkansas plot was inspected in September 1963.

The Chinese chestnut trees planted among the hybrids grew nearly as well as the hybrids. But the preliminary results indicate that not all the individual Chinese trees of seedling origin are fully resistant to the blight. In fact, canker incidence was as high among the Chinese trees as among the hybrids in some plots.

Discussion

Earlier miscellaneous planting of Asiatic chestnut trees demonstrated that Chinese and hybrid chestnut trees exhibit vigorous growth on forested land when not in severe competition from other tree species. However, the percentage of vigorous trees — those averaging approximately 2 feet height growth per year — is believed to be too small to warrant large-scale forest-tree plantings of seedlings for timber production because they could not maintain dominance in competition with the volunteer hardwood species among which they would be planted.

The 27 Chinese trees listed in table 2 represent 5 percent of those planted, and presumably some of these trees will have inherently poor form, or will not be fully resistant to the blight fungus. However, for wildlife plantings, where nut production rather than timber is the primary objective, the Chinese chestnut PI-58602 seedlings may be worthwhile.

Planting seedling chestnut trees for timber production will not be feasible until, either through selection or through breeding, forms are developed that will yield a higher percentage of vigorous, blight-resistant, well-formed trees. As soon as inexpensive vegetative-propagation techniques are developed for chestnut, the very best individual trees can be propagated and used to establish plantations.

Because chestnut is a vigorous sprouter and responds well to coppicing, an area generally needs to be stocked only once. After the first harvest no replanting, as a rule, would be necessary.

The pedigrees of the hybrids shown in table 2 reveal the different approaches used by Clapper and Graves in attempting to obtain the same goal of producing a blight-resistant forest tree. Clapper used first- and second-generation crosses of Chinese and American chestnuts mainly, and backcrosses of the F_1 progeny to the parent species. A few of his crosses, with the Chinese timber-chinkapin (*C. henryi*) and certain intercrosses of Chinese, also showed promise.

Graves, on the other hand, to assure that his crosses would possess sufficient blight resistance, relied heavily upon various combinations of three chestnut species: the American, the Chinese, and the Japanese (*C. crenata*). Sixteen — or possibly 18 — of the 21 Connecticut hybrids listed are combinations of Chinese, Japanese, and American (CJA). The reason for the uncertainty is that some of Graves' crosses were open-pollinated and the parentage is not definitely known.

No attempt is made here to discuss all the reasons for discrepancies in growth rates in the different plots. Some of the contributing factors — such as site, year of planting, and genotype — have been mentioned. Another factor was transplant shock. Certain hardwoods require several years to recover from such shock, and this may be one reason for the poor initial height growth in the New York and New Hampshire plots, which were established as recently as 1954 and 1955, respectively. Still another factor, competition, was apparently an important limiting factor in the Michigan and New York plots. Weather was also an obvious factor: snow damaged the trees of the northern plot in New Hampshire.

Gypsy-moth defoliation was apparently an important limiting factor in the Litchfield, Conn., plot.

The reasons for the slow growth of trees in the Ohio plot were less apparent. Competition from all woody vegetation was eliminated soon after establishment. Possibly encroaching herb and grass cover, or the more alkaline Ohio soil, adversely affected seedling growth.

However, perhaps the most noteworthy finding is not the differences in growth rates — from whatever causes — but the fact that all 15 plots contain some promising trees 9 to 17 years after planting.

Some pertinent questions have been raised by this study: Can satisfactory trees be selected from within a single species — the Chinese chestnut — that possess blight resistance, have good timber-tree possibilities, and yield heavy crops of nuts? Or, can superior trees that meet the above requirements be developed more readily through species hybridization? How resistant are Chinese chestnut seedlings to the chestnut-blight fungus when the trees are grown in competition with other forest-tree species? Among the many large chestnut trees that are beginning to bear in the 15 plots, will certain crosses consistently produce superior offspring? What is the relationship of growth and tree form to blight susceptibility?

Many of the trees in the 15 test plots are still too young and too small for a critical evaluation of their future forest-tree characteristics and nut-bearing capabilities. On the other hand, at least 40 hybrids and 27 Chinese chestnut trees already are showing vigorous growth, excellent forest-tree form, and apparent resistance to the blight. However, a more critical evaluation of all the hybrid trees by geneticists and tree breeders is needed.

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