Nienstaedt

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Notes on the Chestnut:
Breeding, Culture and Botanical Characters of Species and Hybrids

By

Hans Nienstaedt

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INTRODUCTION

More than forty years have now elapsed since the forester at the New York Zoological Garden, Mr. H. W. Merkel in 1904 (85) as the first in the United States realized the seriousness of the new epidemic fungus disease on the American chestnut, Castanea dentata. In an article in the "Tenth Annual Report of the New York Zoological Society" January, 1904 he drew public attention to the matter.

Since then the fungus, now known as the fungus of the chestnut blight Endothia parasitica has spread over the range of the American chestnut with great rapidity. In 1911, only seven years after Merkel found the blight in New York City, the disease had spread over an area from New Hampshire through southern New England and eastern New York to western Pennsylvania, Virginia and West Virginia. (2). In 1925 about 3/4 of the commercial range of the chestnut had been covered (44) and in 1931 Baxter (15) expressed the opinion that most of the virgin chestnut timber would be killed by the blight within 10 or 15 years.

The seriousness of the blight, the most fatal forest tree disease known, (80) called forth a large amount of work in the field of control of the disease and study of the fungus. The initial problem facing the scientists was whether it was an introduced or a native fungus. If the latter was the case and only extreme climatic conditions had caused the sudden epidemic outbreak,the future would not be too grim, and there was a possibility that the fungus would go

back to its saprophytic condition of itself. (28). After the fungus was found in China and Japan (99,100) it was, however, obvious that the fungus was introduced from those countries and it had to be expected that the spread would continue regardless of the climatic conditions, as long as the native chestnut tree did not show any resistance to the disease.

The trend of the control of the disease in the early days, while control still was considered possible, was that of elimination of advanced spot infections, extensive examination of nursery stock before shipment, injection of chemicals in the tree trunks to make them resistant to attack, spraying with Bordeaux mixture and cutting out of the infected spot on the trees, etc. Leading in this type of work was the Pennsylvania Chestnut Tree Blight Commission, which was established in 1911. The work of this organization was short, however, and since 1913 no attempts have been made to check the spread of the disease.

With the discovery of the presence of the fungus in China and Japan and the relative resistance of the chestnut species found there, the Japanese chestnut Castanea crenata, the Chinese chestnut Castanea mollissima Chinese chinquapin Castanea sequinii and the Chinese timber chinquapin Castanea Henryi, new hope was aroused with regard to the possibility of bringing the chestnut back to the American woods. This could be done by the breeding of a new resistant strain of chestnut by crossing the above mentioned Asiatic species with

the susceptible Castanea dentata.

The earliest hybridization work carried out with chestnut was started in 1888 by George W. Endicott of Valley Ridge, Ill. He was working only for the improvement of the nuts in the Japanese chestnut and his work resulted in the variety Boone, which he developed in 1894. (33).

In 1894 Walter van Fleet started his first breeding work also with nut improvement as the main purpose. Van Fleet was working mainly with the crossing of American chinquapin Castanea pumila with the leading European varieties and with Japanese chestnut. He developed one important hybrid the so-called S-8 C.pumila x C.crenata, which since his death has been used in further crossing by the Division of Forest Pathology of the Bureau of Plant Industry, Soils and Agriculture Engineering, United States Department of Agriculture.

The Division of Forest Pathology extended Van Fleet's work beginning about 1928 so that it now includes not only the breeding for better nuts, but also the breeding of a tree of timber type, which can take over the position of the old American chestnut in the forest areas in the eastern United States.

In 1930 Dr. A. H. Graves, then curator of the Brooklyn Botanical Garden, started breeding work with the chestnut. Dr. Graves had since the very beginning of the epidemic been interested in the subject, and had constantly been on the lookout for resistant strains of the American chestnut, which

might have developed, as the blight swept the country--a thing of great importance also in the present breeding work. But not until 1930 did his actual breeding work start. In this year he made his first crosses between C. crenata, which he found as large trees on several estates on Long Island, and C. dentata, hoping that this hybrid would have the resistance of the Japanese parent and the tall, erect growth of the American. These first crosses yielded 10 nuts, but in spite of great care all the nuts molded and not a single plant was obtained. This initial very discouraging result, however, did not prevent the starting of new crosses again the next year, this time with better results, and from this year and up to the present time new crosses have been made every year.

The first crosses made were,as said above, C.crenata x C.dentata, but since 1934 other species of the genus Castanea, both the chestnut proper and the chinquapin, have been used to a large extent. Especially the C. mollissima has, because of its high degree of resistance, been used in many of the most important hybrids developed.

This paper is an attempt to give a botanical description of some of the more important species and hybrids. The native range of the species will be given and in the Chinese and Japanese chestnut the climatic conditions over their native range as determining the area in which they can be introduced in the United States will be discussed. The raising of chestnut trees from the germination of the nuts

to the care of the older plantation will be taken up for consideration including such factors as germination, temperatures required, care of the young seedling, establishment of a plantation under forest cover with requirements of light and site, pruning, cultivation, fertilization, etc. Finally, injuries of the chestnut caused by animals or climate will be described, and means of control considered.

In an appendix the results from an experiment designed to find a way to hasten the germination of the nuts and involving some 1500 nuts of Chinese and Japanese parents will be given.

GENERAL DESCRIPTION of the GENUS CASTANEA (Adams) Mill.

The genus Castanea is a small genus of about 13 species found in southern Europe, eastern United States, southwestern and eastern Asia.

It is composed of deciduous trees or shrubs with furrowed bark. The twigs are usually stout, terete and without true terminal buds. The buds are covered with two or more pairs of slightly imbricated scales. The leaves are ovate, elliptical or obovate in shape with acuminate apex and cuneate to rounded or slightly cordate. The margin is more or less markedly serrate. The veins are thin and run to the slender teeth at the end of the serration. Stipules are present but deciduous. The leaf-scars are semi-circular with 3 or more bundle scars forming an irregular row.

A somewhat more thorough description of the flowering habit of the chestnut may be of interest at this place, it being rather complicated and of great importance in the breeding work.

The chestnut is monoecious. The flowers are borne on the present year's growth in long aggregated catkins. Near the base of the flowering branch the catkins are uhisexual and bear male flowers only; these are found in clusters of 3-7 and the individual flowers consist of a 4-6 lobed calyx with 10-20 yellow stamens with long filaments. Nearer the apex of the branch the much shorter bisexual catkins are

found. They consist of staminate flowers similar to the ones just described, and at the base the pistillate flowers are found, either solitary or in clusters of 2-3 (occasionally 5 or 7) surrounded by the involucre which later forms the characteristic spiny bur. One or several such clusters of pistillate flowers may be found at the base of the bisexual catkins. (75.93.95.101.103.).

The shedding of the pollen falls into two distinct periods. First the unisexual staminate catkins at the base of the flowering branch shed their pollen, and not until several days later do the male flowers on the bisexual catkins mature. The pistillate flowers may begin to bloom either before or after the shedding of the pollen from the basal unisexual catkins. (101.103). This has been called duodichogamy as opposed to dichogamy, where there is only one time of pollen shedding and one for blooming of the female flowers, the two periods occurring at different times. The pollen from both types of catkins has been proved to be fertile. (103).

As stated above, the pistillate flowers may start to bloom either before or after the pollen shedding of the unisexual basal catkins, thus being either protandrous (♂ flowers developed first) or protogynous (♀ flowers developed first). Some trees are almost synacmous, (♂ and ♀ flowers maturing at the same time). The protandrous trees usually have a long period of staminate blooming and a relatively short period of blooming of the pistillate

flowers; in the case of the protogynous trees the situation is reversed. The protandrous trees are the most common..(103).

The chestnut is well known for its almost complete self sterility and the question is then, how does the above described habit of flowering influence this, and are there any other factors affecting the result. The duodichogamy involved has the effect, that the period in which close pollination or self-fruiting can occur is limited. If we consider a protandrous tree, it is obvious that no close pollination can occur in the beginning of the period of blooming when only male flowers are mature. In the mid-period of blooming, however, both male and female flowers are developed and close pollination is possible; thereafter, at the end of that period the pistils have ceased to be receptive, and although pollen still is produced, no close pollination can occur. In the protogynous tree it is again (due to the long period of pistil blooming and the short period for pollen production) the two end periods in which close pollination is impossible and a cross pollination necessary for the production of fruits. (103).

It is thus obvious that although the condition of duodichogamy shortens the period in which close pollination can occur another factor must be present to obtain self-sterility. (103).

Vilkomerson (103) made several controlled close pollinations (a total of 464 flowers) and obtained only 4 nuts..

Stout examined 2 separate chestnut trees in California and found that although the burs reached full size, not a single fertile nut developed. A similar example was noted by the writer this fall in Cheshire, Conn. Here a big Japanese chestnut tree bore a heavy crop of burs, but only one nut was found; this has been the case with this tree also in the past. Apparently the pollen from the same tree is incompatible, so that this and duodichogamy are the two factors resulting in the self-sterility of the chestnuts.

Cross pollination takes place with ease. An examination of our pollination records from 1935 to 1946 showed that of 169 different combinations tried, 130 or 77% were successful at least once. The 23%, which were unsuccessful, are in all cases, combinations which only have been tried a few times, and not enough to prove definitely that the pollen is incompatible.

Finally it may be stated that parthenogenetic development of nuts has been found in the case of C. pumila by Morris. (87). After removing the staminate flowers of the bisexual catkins the pistils were bagged and although no pollen was applied, he obtained fertile nuts, which however showed certain peculiarities, such as chlorophyll in the cotyledons which were protruding through the seed coat before the nuts were fully developed. Also the plants which developed differed from normal, some having much larger, others much smaller leaves.

The fruit is a light to dark brown (sometimes with darker stripes) nut, glabrous or tomentose, ovoid in shape, acute and with a pointed apex which bears the remnants of the style. The hilum is a large pale scar which more or less completely covers the base of the nut. The nuts are borne solitary or in clusters of 2-3 in a 2-4 valved involucre. The involucre, which later forms the bur, is globose or short oblong; the insides of the valves are more or less tomentose, and the outside pubescent or tomentose and covered with rigid hairy or glabrous often much-branched spines. The cotyledons are large and fleshy, more or less sweet, and have a high food value, containing a large proportion of starch.

Studies of the chromosome number have been carried on by Wetzel. (104). He found a haploid number of 11* in the species C. sativa and C. crenata. Moreover, he found that in the order Fagales the number was constant within the various genera; it thus seems justifiable to assume that the same number will be found in all species of the genus Castanea.

* After this thesis was written a reference (Richens, R.H.: Forest Tree Breeding and Genetics. Imp. For. Bur. Oxford, England, 1946) was found, which gives the haploid number for C. dentata and C. sativa as 12

A DESCRIPTION of the INDIVIDUAL SPECIES and HYBRIDS

I. SPECIES

The American Chestnut Castanea dentata (Marsh) Borkh

The American chestnut is or rather was, since the chestnut blight has practically killed off the species within its natural range, a large fastgrowing and well formed timber tree in the forests in eastern United States.

In the forest the tree reached large dimensions, generally from 70-90 feet in height and 3-4 feet in diameter, but trees 120' high and 6' d.b.h. were not at all uncommon. (75,93). The growth rate is comparatively rapid (10) and Zon (109) gives the following data for height growth

*

Age	Height		Mean Annual Height growth of seedlings
	Seedlings	Coppice	
years			
10	7'	23'	.70'
20	17'	42'	.85'
30	33'	57'	1.10'
40	52'	69'	1.30'
50	64'	77'	1.28'
60	73'	83'	1.22'

Table #1. The height growth of C.dentata

These figures compare fairly well with the figures obtained from measurements taken in the plantation in Hamden. 15 trees of ages from 6-12 years and all originating from

* Computed by the writer.

seeds showed an average mean annual height growth of .85' with a range of .19' - 1.37'. Figures are not given for coppice growth due to the difficulties involved in an accurate age-determination without cutting the shoots.

The range was as shown on the map below, the Northeast, the Appalachian Region and part of the Ohio and Mississippi Valley.

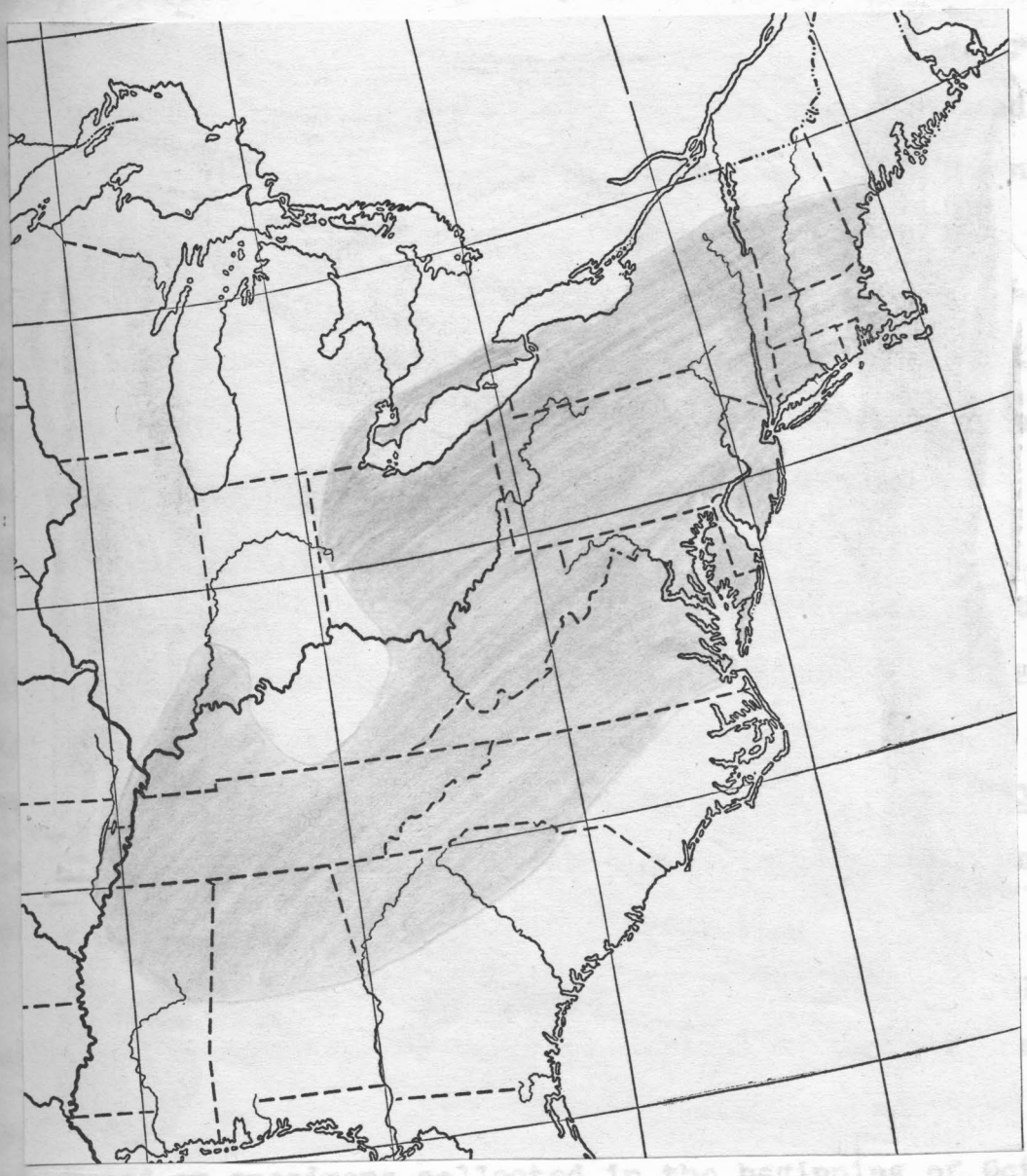

Figure #1.
The range of C. dentata

Among the trees within its range it was one of the most valuable species, due to the very excellent characters of the wood. The heartwood is very durable, rating as high as the cedars in this respect and therefore being well suited for telephone poles, construction timbers and the like. Other products from chestnut were mine timbers, fence posts, shingles, wood for boxes and crates, for interior finish, for tubes and water pipes, for ribs for ships, for agricultural implements, for veneer and a great variety of other goods. The bark as well as the heartwood has a very high tannin content (7-12%) and it has therefore been extensively used in tannin manufacturing in the States. Finally the high quality of the nut must be mentioned, it being far superior to the European and Japanese nut in sweetness and consistency of the meat; the Japanese and European being rather tough.

Botanical features*

Branchlets glabrous or nearly so. Rich brown at least on the upper surface, the lower surface of young branches greenish with many small white lenticels. Bark in the young tree smooth and grey (somewhat darker than on Fagus grandifolia); later, dark brown, divided by shallow irregular often interrupted fissures into broad flat ridges; (13);

Leaves 6-8½" long 1½"-2½" wide; elliptical to obovate; apex long acuminate, the base symmetrical or asymmetrical,

* The botanical descriptions are, where nothing else is stated, based on specimens collected in the beginning of October, 1947 in the plantation of the Connecticut Agricultural Experiment Station at the east end of the Sleeping Giant Mountain, Hamden, Conn.

cuneate to acute; upper surface dull yellow-green, lower surface pale yellow-green; glabrous, but according to Rehder with minute glands on lower surface when young. Sargent (95) calls it a fine cobweb-like tomentum. Serration coarse with bristle-tipped teeth, with 17-20 pairs of fine parallel veins.

Buds about twice as long as wide, sometimes with short hairs near the apex; somewhat divergent, light brown, outer scales, which usually do not extend to the tip, somewhat darker in color; phyllotaxy 1/2 or 2/5.

Flowers. Blooms in Connecticut, in the beginning of July (1-12 July). The staminate catkins are 6-8" long, the bisexual 2⅛"-5" long with 2-3 involucres of pistillate flowers near the base. (95). The species starts to bear when it is 10-15 years old.

Bur. 2-2½" in diameter, pubescent and at the outer surface covered with long slender and very rigid glabrous spines, which are much-branched near the base. Opens readily in late September into four valves. Inner surface densely covered with silky hairs.

Nuts. 2-3 together in the bur, rather small compared with most other species, about 1/2-3/4" across*, somewhat wider than long, with silky yellow-white hairs from the middle to the apex. Seed testa densely covered with a thick tomentum, easily removed. Meat sweet and crisp. Reed (90) gives the number of nuts per lbs. as 130-200 with a minimum of 86.

* Both Sargent and Harlow says 1/2-1" across, but no nuts as big as that was found by the writer.

The Japanese Chestnut: Cantanea crenata Sieb. & Zucc.

Beattie (18) states that the Japanese chestnut is found from the middle of Hokkaido in the north to the middle of Kyushu in the south and in the southern part of Korea.

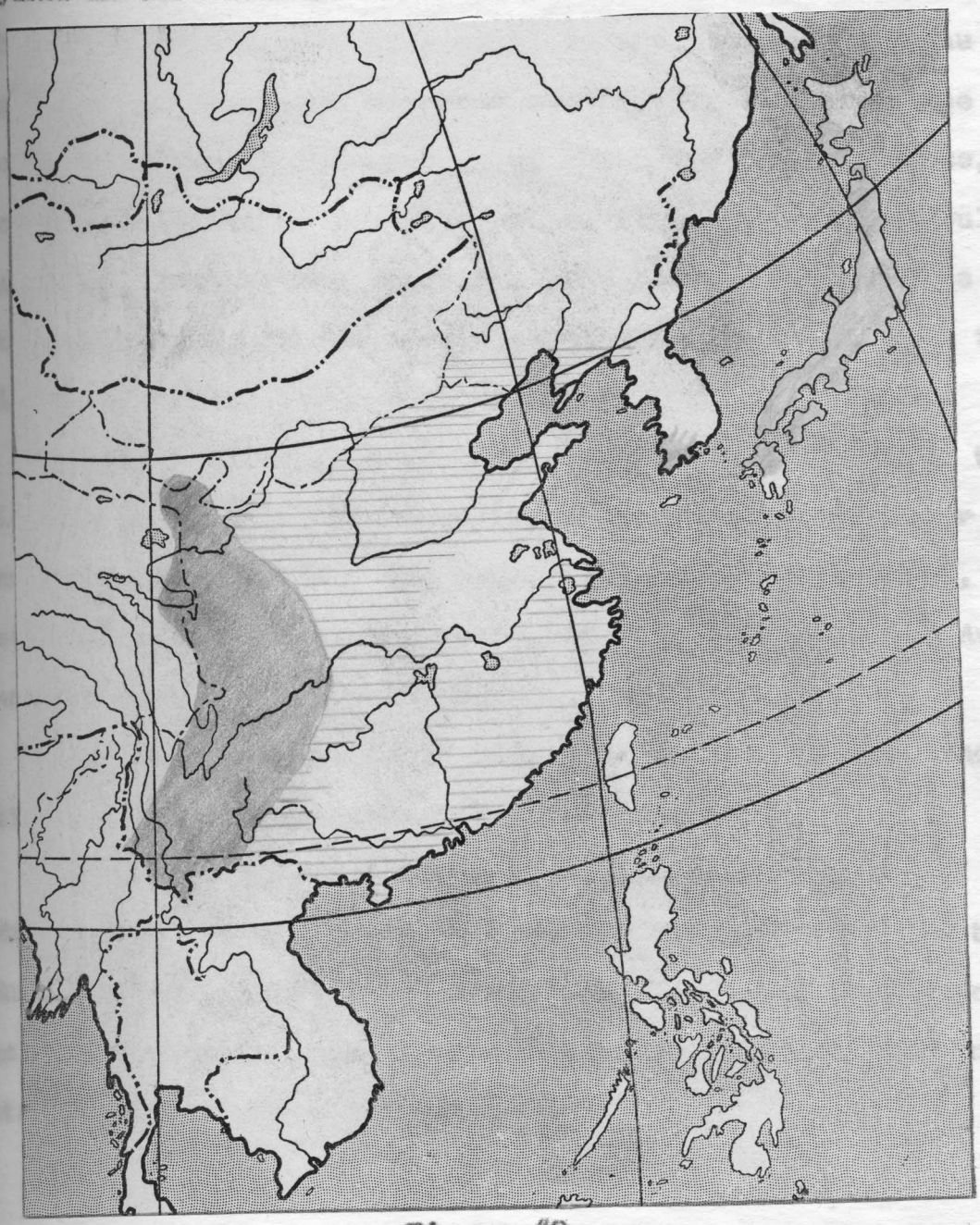

Figure #2
The range of Castanea crenata and Castanea mollissima.
C. crenata
C. Mollissima natural
C. mollissima cultivated

Schenck (96) gives a somewhat more definite description of the range. He discloses that it goes as far north as Sapporo and Tomakomoi on Hokkaido, here growing in the "plainforests" (Ebenenwaldern). In the south it gradually climbs higher and higher up in the mountains until in the middle of Kyushu it grows at an elevation of about 3,000'. In the south the species is one of the members of the mixed hardwood type, the other species being from the genera Fagus, Quercus, Populus, Aesculus, Juglans and Magnolia. The best development is attained in the northern provinces of Aomori and Akita on the island of Hondo.

Japan's climatic condition is strongly affected by the insular position of the country, the summer being rather cool and the winters mild. The precipitation is fairly high, and well distributed over the year, although the months of August andSeptember are the rainy season.

The following table II will give an idea of the conditions. The data are taken from Schenck. (96).

If the data from Japan are compared with Table III which gives the similar data from the chestnut range in the United States, it will be possible to draw some conclusions as to the area in Japan from which introduction in the United States can be made with most success.

Precipitation in mm

April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Total P Average T
8.5	12.9	16.7	19.9	20.6	17.2	11.5	6.3	1.1	9.6
203	241	340	351	314	603	192	129	85	2902
8.6	13.1	17.6	21.6	24.0	17.9	12.1	6.0	.6	9.7
133	180	184	139	225	366	167	271	186	2255
8.0	12.5	17.0	21.3	23.4	17.3	11.5	5.4	0.0	9.3
83	116	114	91	140	226	114	167	115	1416
7.9	10.8	15.0	19.2	22.0	16.6	10.8	4.3	-1.0	8.3
100	134	146	104	170	276	126	204	140	1704
6.6	10.3	13.9	18.0	21.2	16.9	11.2	4.4	-1.8	7.9
61	101	67	48	103	146	103	95	89	998
5.2	10.4	148	188	20.7	16.1	9.5	2.9	-3.4	6.8
57	64	64	91	96	129	107	100	94	1012
5.9	10.3	143	18.4	21.0	16.5	10.4	3.6	-2.6	7.4
61	100	66	148	102	146	103	94	93	1098

Table II. Climatic data from Japan

Name of Station	Latitude	Altitude	Average temperature in C, and	Jan.	Feb.	March
Besshi	33°51'	950 m	T	.2	-1.9	2.2
			P	137	113	194
Akita II Hardwood zone	39°45'		T	-1.8	-2.2	1.4
			P	152	110	142
Aomori I Thujopsis zone	40°58'		T	-2.4	-2.8	0.8
			P	94	68	88
Aomori II Cryptomeria and Thujopsis mixed	40°30'		T	-3.1	-3.3	0.2
			P	114	83	107
Hakodate	41°46'	3 m	T	-3.3	-3.1	.2
			P	5.8	59	68
Sapporo	43°04'	17 m	T	-6.3	-5.4	1.7
			P	82	66	62
Tamakomai	42°40'		T	-4.5	-4.2	-.8
			P	58	59	68

the United States

and Precipitation in mm, (P)

April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Total P Average T
8.0 66	14.9 74	19.9 89	22.6 89	21.4 91	17.4 79	10.9 69	4.3 69	-2.0 61	9.1 878
7.6 81	13.7 97	18.6 91	21.4 109	20.0 109	16.2 91	10.0 91	3.8 94	-2.5 89	8.4 1108
8.6 84	14.7 89	19.6 81	22.6 102	21.2 107	17.6 86	11.8 91	5.4 94	-0.7 86	9.9 1092
8.3 97	14.3 94	19.3 79	22.2 109	21.2 114	17.7 86	11.9 94	5.7 91	0.1 97	9.9 1166
10.4 76	15.7 89	20.3 99	22.7 97	21.8 86	18.7 86	12.2 76	5.6 69	-0.1 79	10.8 993
10.5 79	16.6 94	21.2 102	23.7 97	22.5 99	19.0 86	12.6 76	6.2 59	0.7 79	11.3 995
12.5 79	16.8 89	20.7 102	22.3 114	21.9 109	19.3 76	13.3 71	7.7 59	3.8 81	12.8 1027
14.6 127	18.9 107	23.0 109	24.8 124	24.3 104	21.6 79	14.9 79	8.8 94	4.8 145	14.5 1345
16.2 145	21.1 76	25.0 107	26.7 122	25.6 137	22.8 86	16.2 53	11.7 81	6.8 127	16.2 1363

Table III. Climatic data from

Name of Station	Latitude	Altitude		Average temperature in C,(T) Jan.	Feb.	March
Albany, New York	42°38'	29 m	T	-4.7	-4.6	0.8
			P	61	61	69
Amherst, Mass.	42°22'	68m	T	-4.6	-4.6	0.9
			P	86	81	89
Hartford, Conn.	41°49'	48 m	T	-2.4	-2.7	2.9
			P	86	89	97
New Haven, Conn.	41°19'	38 m	T	-2.0	-1.9	2.5
			P	99	99	107
Dennison, Ohio	40°25'	259 m	T	-1.7	-0.5	4.6
			P	91	61	84
Harrisburg, Penn.	40°15'	109 m	T	-1.2	-1.0	4.4
			P	79	71	74
Asheville, N.C.	35°34'	689 m	T	3.4	4.0	8.3
			P	71	79	97
Tallahassee, Tenn.	35°20'	137 m	T	3.9	5.0	9.8
			P	132	117	157
Newburg. Ala.	34°27'	200 m	T	4.5	6.2	11.2
			P	122	119	188

The factors to be considered in this connection are the following: (a) Temperature throughout the year and maximum and minimum extremes; (b) the date for the first fall frost and the last spring frost; and finally (c) precipitation, which is rather important in the case of the chestnut, a genus quite sensitive with regard to drought. In the present paper only the introduction in Connecticut will be considered, represented by Hartford and New Haven in the climatic data, Table III. It will be seen that the stations in Japan which show the closest resemblance to Hartford and New Haven are Akita II and Aomori I and II. Akita II, however, has a precipitation about twice as big as that of Connecticut, and specimens from this section of Japan would probably be less suited for this state than specimens from the province of Aomori where the precipitation is only about 300 mm higher than in New Haven and Hartford. Extreme temperatures are for Aomori II given as 30.8°C maximum and -19.0°C minimum while New Haven has had a high of 38.3° and a low of -25.5°C (a low of -24°C is reported by Graves 1934 (57), a temperature of -25.5°C, however, should not be fatal to the Japanese chestnut according to Clapper and Gravatt (27), who state, that temperatures from -32°C (-20°F) and down are fatal. That some winter injury may occur at this temperature (-25.5°C) is undoubtedly the case, and introductions even from further north may be advisable. Data on the late spring frost and the early fall frost are unfortunately lacking so

that a discussion on this important point is impossible.

In Korea where the species according to Beattie (18) is found under wild conditions, the climate is much more severe than that in Japan, with less precipitation, and a pronounced rainy season in the summer. Temperatures as low as -20°F are common in the winter without snow cover. It seems, however, doubtful that introductions from conditions such as those, which still differ notably from the American would be more successful than those from Japan.

Most unfortunately, the data concerning the origin of the Japanese stock at Hamden are incomplete; it is therefore, impossible to compare the hardiness of the different trees. In the future an exact description of the native home of every foreign tree planted must be obtained whenever possible.

Castanea crenata is only a small tree with a low setting crown, which occasionally attains heights over 10m (30') with a maximum d.b.h. of up to 5' (96)* and it is only of minor importance in the deciduous hardwood forest in Japan. The rate of growth seems to be somewhat faster than that of C. dentata while they are still young. 11 trees measured in Hamden had a mean average height growth of .99' with a range of .50'-1.33'. The range in age being 6-17 years.

The wood consists of a narrow light brown zone of sapwood and a dark brown heartwood, it is elastic, easy to split and very durable. The most important commercial uses are for ties

* This seems to be the common opinion among botanists. Beattie (18) states that 25 year old Japanese planted chestnuts measure 35-40' with a d.b.h. of 5-6".

and fuelwood. (96). Also for charcoal it is used to some extent, in this case grown at a short rotation of 15-20 years. The tannin content is about the same as that of American chestnut,and it is used for tannin extraction.

Botanical features:

Branchlets when young fine pubescent, late in the season only a few fine hairs remain near the tip of the branch, otherwise glabrous. Bark when young reddish to reddish brown where exposed to light, greenish underneath, many comparatively large white lenticels. Older bark dark reddish brown, soon becoming rough and shallowly furrowed and more greyish in color.

Leaves 4-8" long, 1-1¾" wide; oblong to oblong-lanceolate with short acuminate apex, base asymmetrical or nearly so acute through rounded to subcordate. Upper surface glabrous, lower surface with a multitude of small yellowish white glands, giving the whole lower surface a yellowish-white color; upper surface shiny light green. Nerves 19-25 pairs, hairy above, with hairs and glands below; serrations very fine, teeth reduced to bristles.

Buds with short tomentum near tip, two outer budscales reddish where exposed to light, tip yellow; conical in shape without distinct point, somewhat divergent. Phyllotaxy 1/2.

Flowers may develop when the trees are about 4 years old. Blooming in Connecticut occurs from about June 24th - July 5th-6th. Schenck (96) mentions the length of the catkins

as 80-120 mm (4-4⅝"), and does not distinguish between the unisexual and bisexual catkins.

Bur about 2¼" in diameter (2-2½"). Short pubescent on the outer surface, spines with a few glands and hairs somewhat stouter than those of C. dentata. Silky hairy on inner surface but much less than C. dentata. Does not open readily, but is often shed from trees unopened.

Nuts 1-7 in the bur. About 3/4"-1" wide and 7/8" to 1-1/8" high, light brown in color with darker stripes from hilum to apex. Hilum covers the whole base of the nut. Only a few short hairs toward the apex. Taste not as good as in C. dentata; meat of a consistency somewhat like raw potatoes; seed testa difficult to remove. Reed (90) gives the number of nuts per pound as 40-60 with a minimum of 16. Ripens generally in September and early October, but some varieties already as of the end of August.

The Chinese Chestnut, Castanea mollissima Bl.

The Chinese chestnut is found planted extensively throughout China. Shun-Ching Lee (82) who does not distinguish between planted and wild distribution, mentions the species as being present in the following provinces, Hopei, Shantung, Shensi, Kansu, Chekiang, Kiangsi, Hupeh, Szechwan, Yunnan, Kweichow, Fukien, Kwangtung, or in other words, over the entire China proper with the exception of the provinces Kiansu and Honan between Hwang-Ho and Yangtze to the east and Hunan between Yangtze and Canton to the south. Schenck (96) declares that the native home is the mountains in western and southwestern China; to this must be added northwestern China where it was found wild, growing under forest conditions by E. H. Wilson. (18). According to the above-mentioned three references Map #2 has been made. A glance at Table #IV will show that the introduction from China of C. mollissima is more difficult than that of C. crenata from Japan, the climatic conditions being so very different from that of Eastern United States. Eastern and southern China even on the higher altitudes are much warmer than in the States and there is a pronounced rainy season in the summer in which the precipitation is concentrated. Introductions from these parts of China must be expected to be unsuccessful.

The wild chestnut which must be expected to be more desirable for forestry purposes than the low spreading orchard tree is as stated found in the western and northwestern part of China proper. The climatic data from the northwestern

Table #IV. Climatic data from China

Name of Station and Province	Latitude	Altitude		Average Temperature in C (T) and Jan.	Feb.	March	Apr.	May
Peiping (Chahar)	39°50'	52 m	T	-1.9	-3.7	-3.3	11.5	18.6
			P	1	2	7	6	32
Tientsin (Hopeh)	39°09'	5 m	T	-4.1	-1.8	4.7	12.7	19.5
			P	4	2	10	17	27
Taikang (Honan)	34°01		T	2.9	2.6	9.7	16.3	21.9
			P	17	13	11	35	3[illegible]
Nanking (Kiangsu)	32°05'	16 m	T	3.1	4.2	8.3	14.0	19.9
			P	41	50	75	101	8[illegible]
Hangchow (Chekiang)	30°11'	10 m	T	4.7	5.4	9.1	15.0	22.2
			P	62	85	137	146	11[illegible]
Itch'ang (Hypei)	30°42'	518 m	T	5.6	7.0	11.5	17.6	22.[illegible]
			P	20	29	54	101	12[illegible]
Anyo (Szechwan)	30°06'		T	7.0	8.4	11.0	16.0	20.3
			P	15	20	33	91	8[illegible]
Chunking (Szechwan)	29°34'	230 m	T	9.2	9.9	14.2	19.7	23.
			P	17	20	35	102	14
Chet'sien (Kweichow)	27°20'	450 m	T*	5.9	7.0	14.4	16.0	20.
			P*	30	28	28	85	16
Yunnansen (Yunnau)	25°04'	1980 m	T	9.1	10.3	15.5	19.9	21.
			P	13	13	14	18	9
Kiukiang (Kiangsi)	29°45'	20 m	T	4.7	5.6	10.0	16.7	21.
			P	63	83	151	181	17
Yotcheou (Hanan)	29°24'		T	4.8	5.4	8.8	14.6	19.
			P	32	73	143	153	15
Foutcheou (Fukien)	25°59'	20 m	T	11.7	10.9	13.5	18.0	22.
			P	47	96	115	122	15
Canton (Kwangtung)	23°07'	15 m	T	13.7	14.9	17.2	21.0	24.
			P	50	75	76	149	25
Tsingtao (Schangtung)	36°04'	74 m	T	0.4	0.4	4.7	10.4	16
			P	11	10	20	38	

* The precipitation is taken from Kweiyang in the same province.

and Precipitation in mm (P)

May	June	July	August	September	October	November	December	Total P Average T
18.6 32	24.7 60	26.1 267	24.4 141	20.1 44	12.7 20	4.1 10	-1.9 4	11.5 594
19.5 27	23.7 64	26.1 174	25.9 133	20.9 48	14.2 16	4.5 10	-2.4 3	12.0 508
21.9 35	25.0 118	27.2 177	26.7 175	22.2 133	17.9 35	9.6 24	4.8 2	15.6 775
19.9 82	24.0 183	27.4 207	27.3 116	22.6 94	17.3 50	10.3 41	4.5 30	15.2 1070
22.2 111	24.5 249	28.3 152	27.9 176	23.2 135	18.2 107	11.8 82	6.0 60	16.4 1502
22.4 123	26.4 155	29.0 211	29.0 170	24.4 100	19.2 84	13.4 36	8.0 14	17.8 1097
20.3 84	23.4 160	25.7 153	25.2 163	22.0 94	17.7 86	12.5 25	6.9 14	15.2 938
23.1 141	25.1 181	28.0 143	29.1 131	24.4 147	19.4 115	14.8 50	10.2 22	18.2 1104
20.7 166	25.4 165	27.3 245	25.8 88	21.8 165	113	45	6.6 14	1171
21.0 94	22.1 155	22.1 239	21.3 207	18.3 136	17.3 92	13.3 44	9.7 15	16.7 1040
21.9 174	26.2 243	29.8 143	29.1 131	25.0 89	19.2 97	13.0 68	7.4 43	17.4 1466
19.5 152	23.8 224	26.2 115	27.9 115	21.2 74	16.1 97	10.1 110	4.2 34	15.2 1322
22.4 150	26.8 208	28.9 161	29.1 182	26.6 214	22.6 51	17.7 41	13.1 47	20.1 1434
24.8 254	26.9 265	271	27.0 283	27.3 135	24.1 63	20.2 44	16.5 36	1701
16.1 41	20.0 85	23.3 156	24.9 147	21.2 84	16.0 33	8.1 21	1.4 16	12.2 662

part of the country are incomplete and not very reliable, but that the conditions here are more severe than in eastern United States is a fact, and as emphasized by Beattie (18) trees introduced from the colder parts of China are apt to suffer from late spring frost, because the warm weather early in spring in the United States brings about the leafing so early that they later will be damaged by frost. A somewhat similar condition may also be found in the fall where the growth continues so long that injury from the early fall frost occurs. The best places to find the species will probably be in the Northwestern part of the province Szechwan or in the southern part of Kansu, although it is hard to draw any definite conclusions due to the lack of information. Orchard trees will undoubtedly be introduced from the area around Peiping and Tientsin most successfully. Here the temperatures are much like those of Connecticut, although the extremes are less severe than in this state, the absolute minimum being around -18°C compared with -25°C in New Haven and Hartford. Thus some winter injury must be expected.

Here as in the case of the Japanese stock, information with regard to the origin of the trees is incomplete. None of the trees is, however, from the areas from which importation would be expected to be the best. In 1935 lots were received from Chekiang and Hupeh, in 1936 from Hopeh and in 1941 from Kiangsu, all eastern provinces and of a rather southern latitude. One lot was received in 1935 from the Chahar province in the north, but it does not seem to be more hardy than the other lots, and may be an example of Beattie's

statement that trees from the coldest parts of China cannot be expected to be the most hardy.

Castanea mollissima does not attain any large size although it is somewhat larger than Japanese chestnut. A maximum height of 20 m (60') is occasionally reached with a corresponding d.b.h. of about three feet. The form is spreading like an orchard tree with low setting crown. The growth rate seems to be a little faster than that of C.dentata. For 60 trees of ages from 3-18 years an average mean annual height growth of .96' was found.

Information about the commercial importance of the species in its homeland are lacking as far as the wood goes although Lee (82) calls it a "most valuable timber tree--." The tannin content is about the same as in the American chestnut. (18).

The nut, however,is highly appreciated in China for its high food value and excellent taste, this being the reason for the extensive planting of the tree throughout that country.

Botanical features:

Branchlets, long pubescent and with some longer yellow hairs when young, later in the season only pubescent just below the pseudoterminal bud; previous year's growth greyish to light grey brown, with several narrow furrows of darker color, and with several large grey lenticels. Bark on older branches shiny dark brown, becoming furrowed at an early stage and dark grey brown in color.

Leaves, 5-7½" long, 2-3" wide, broad elliptical to oblong, sometimes slightly ovate. Apex short acuminate, base rounded

to truncate, symmetrical or asymmetrical. Lower surface with a characteristic dense greenish white tomentum; shiny and dark green, on upper surface. Serrations uniform and coarse; 13-18 pairs of veins, glabrous above, tomentose below, at least earlier in the season.

Buds comparatively large, broad, ovoid in shape, with dense short pubescence, a short pointed apex, greyish in color, somewhat divergent. Phyllotaxy 1/2, but to some extent irregular.

Flowers develop about the third or fourth year, but do not usually amount to much until the 10th-12th year. (92). In the plantation at Hamden the first flowering occurred in 1933 on a tree received as a two year old seedling from the United States Department of Agriculture in 1929, the tree thus being 7 years old. (55). The productiveness varies very much from year to year among the individual trees, some trees bear heavy crops annually, some biannually, and others with irregular intervals. (19). The blooming starts at Hamden about June 27th (a single year as early as the twenty-second) and ends about the tenth of July. Schenck (96) gives the length of the male catkins as 3-4".

Burs 2½-3" in diameter, long pubescent on the outer surface. Spines hairy and much branched. Inner surface long silky hairy. Opens readily by three or four valves and often remains on the tree for a short time after the nuts are shed.

Nuts 2-3 in the bur, very variable in size. The measurements taken by the writer at Hamden were 3/4" - 1" wide and 7/8" - 1-1/8" high. Blake (19) gives the width as .82 - 1.27".

Also the number of nuts per pound varies very much. Blake (19) gives 44 large and 144 small nuts per lb. Reed (90) mentions 50-75 with a minimum of 29 nuts per lb. Light brown to mahogany brown in color, sparsely covered with short white hairs becoming denser towards the apex. Seed testa thin and easy to remove. Meat of high quality, like the American nut, sweet and fine textured.

The Chinese Dwarf Chinquapin Castanea Seguinii Dode.

The Chinese dwarf chinquapin has its native home in China from Ningpo in Chekiang in the east and along the Yantsze river valley to Szechwan in the southwest. It is also found in Shensi and Kweichou.(94). Sargent (94), however, says that it is not reported in the western part of Szechwan by Wilson, and differs in this statement from Lee (82), who includes Yunnan to the south and west of Szechwan in the list of provinces in which it occurs. This province has therefore been included in Map #3.

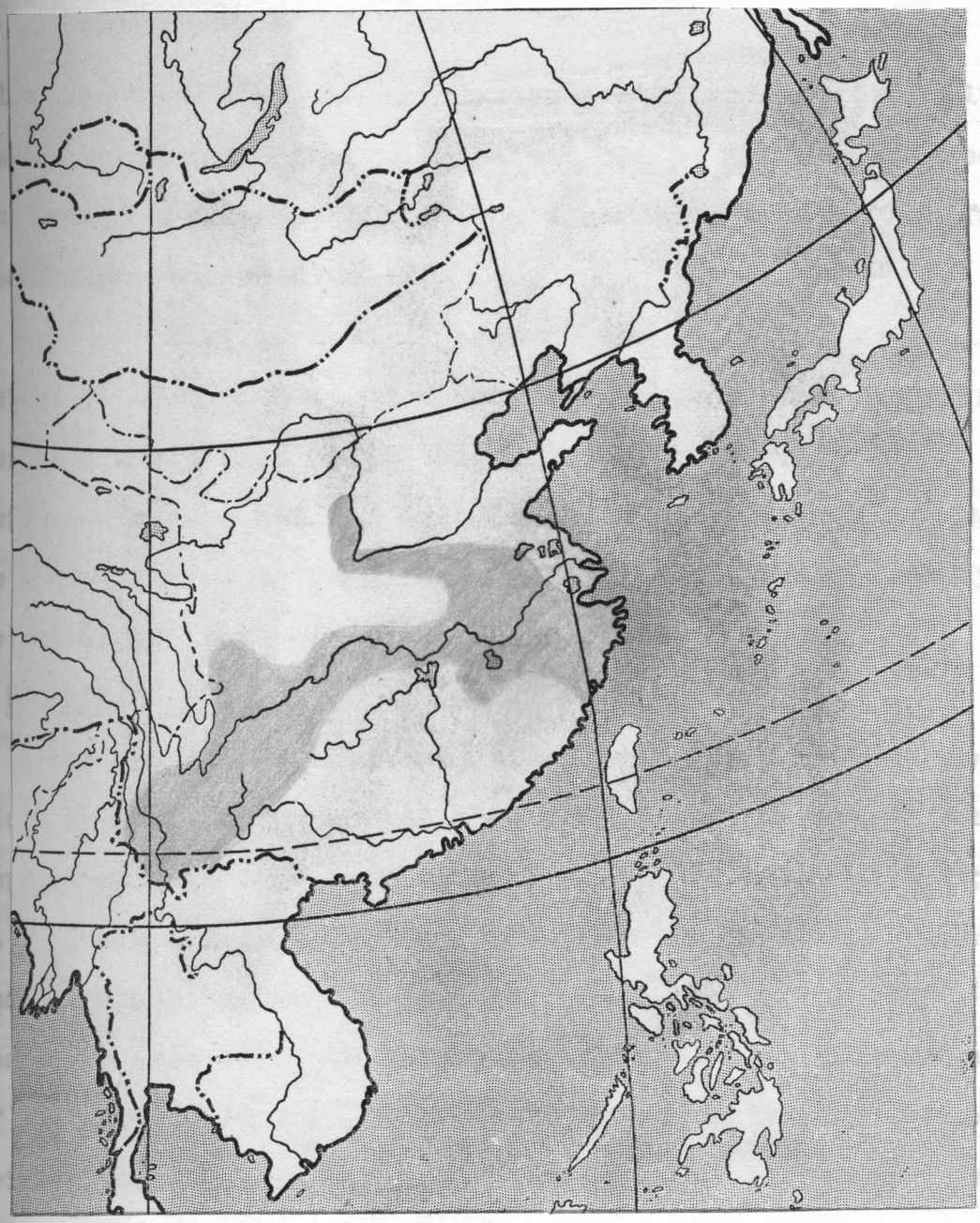

Figure #3

Range of Castanea seguinii

The species usually grows on the hillside at an altitude of 3000 - 4800 feet, here forming dense thickets.

The climatic conditions over most of the range of the dwarf chinquapin are much milder than in eastern United States. In Shensi, however, the temperature must be much lower (data are lacking) but introductions will probably be unsucessful

also from here like that of Castanea mollissima. Thus, it cannot be expected that C. seguinii can be introduced successfully in Connecticut; but it could undoubtedly be grown further south with good results.

C. seguinii is a small tree or shrub, which reaches a height of 10-30', but under very favorable conditions it may form a shapely tree 30-45' high with a diameter of 5-9". Neither the wood nor the nuts have any great commercial value. As the specimens in Hamden are killed back almost annually by frost, the rate of growth has not been computed.

Botanical features:

Two types of the species are growing in the Hamden plantation, which differ somewhat from each other in certain characteristics. One type originated from nuts received through Mr. R. C. Ching and collected in 1935 near the Lu-Shan Arboretum and Botanical Garden at Han-Po-Kou, Lu-Shan, Kiukiang, China; the other were received through the United States Department of Agriculture in 1929, the origin of which is unknown to the writer. The following description is based on the one received from Mr. Ching in China.

Branchlets when young short pubescent, later glabrous or nearly so. Young twigs greenish brown, later turning dirty brown; many large white lenticels; older bark dark brown.

Leaves 3½ - 5" long, 1-1½" wide, oblong to obovate. Apex long acuminate, base cuneate to acute, seldom obtuse to rounded, symmetrical or asymmetrical; serrations fine. Lower surface

densely covered with numerous minute glands which gives the surface a whitish color. Upper surface light green, somewhat dull; 13-16 pairs of veins, pubescent on upper as well as lower surface.

Buds not present on the blooming shoots, short hairy near apex, oblong in shape, with blunt apex. Apex greenish to greenish white. The two outer budscales, which extend a little over half-way up the bud, light brown to reddish brown, somewhat divergent. Phyllotaxy 1/2.

Flowers. As far as known to the writer the flower development starts early, but unfortunately no references have been found on the subject. The plants developed from Mr. Ching's nuts were used for the first time in the hybridigation work in 1940 when the plants were 5 years old. The plants do not bloom continuously throughout the season.

Burs with long fairly rigid spines. Spines short, hairy, spherical and with a diameter of 1-1¼", occurring towards the apex of present year's growth and solitary.

Nuts small about the size of a pea. 1-3 in the involucre, dark brown, without much taste.

The specimens from the United States Department of Agriculture differ from this description in the following respects:

Branchlets glabrous or with a few widely separated short hairs. Young shoots green, later turning to a mauve-brown color. Lenticels smaller, yellower and more numerous than on the above-mentioned form.

Leaves, 3½-6½" long 1-1⅝"wide with a shorter, acuminate

cording to Lee (82) in Kwantung. According to Schenck (96)

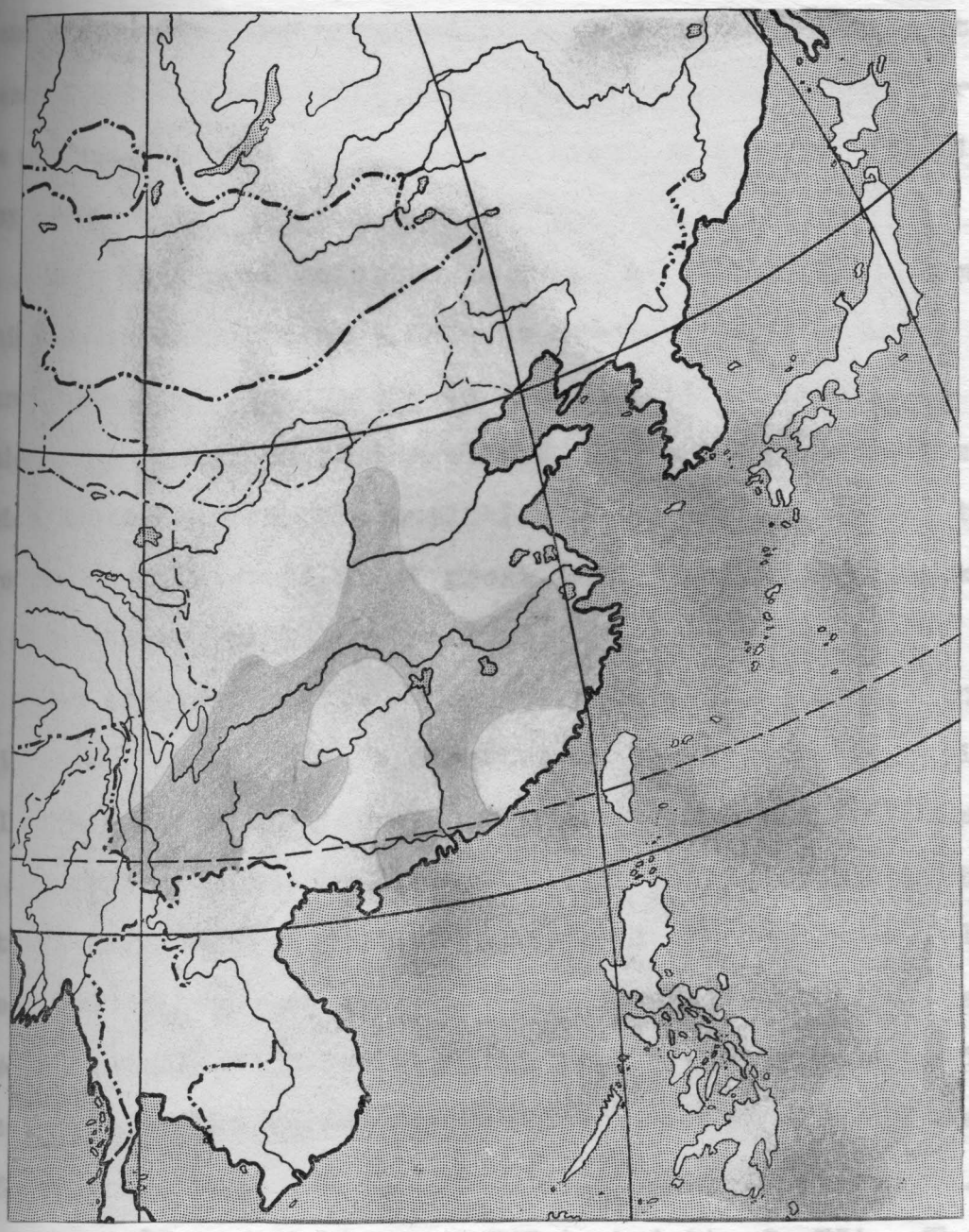

Figure #4

Range of Castanea Henryi

it is found in Shensi east of Hwang-Ho in the North, while C. seguinii is found in Shensi west of the river.(94). The

ranges each bearing a close resemblance to the other. The introduction of C. Henryi into eastern United States is attended with the same problems as have been described in the case of the Chinese dwarf chinquapin. It cannot therefore be expected that C. Henryi can be grown in Connecticut with any success.

This is a most unfortunate state of affairs, the timber chinquapin being the only Chinese chestnut species which compares with Castanea dentata in growth habit; moreover it is said to be resistant to the blight. It is thus the only species which possesses both the qualities which are desired in the crosses and it would be of great importance if the stock could be incorporated with the hybrids.

The species reaches under the best growing conditions, heights of 75'-90' with a diameter of 2½'-3' with a straight bole and a crown high above the ground. The rate of growth is not mentioned in the literature and it is impossible to get satisfactory figures from the Hamden plantation, where all but one specimen are winterkilled to the ground year after year. The individual which has survived comparatively uninjured was received from the United States Department of Agriculture in 1935 as a two year old seedling, thus being 14 years old. It measures 10½' in height or an MAI in height of .75'. The growth habit is not of the timber type, but so far no cankers have been found.

Botanical features:

Branchlets glabrous, present year's growth with pronounced

ridges, greyish green to green brown in color; previous year's growth greenish brown in color. Lenticels are not very numerous. The bark remains, as far as is known, fairly smooth and of a light grey-brown color for a number of years.

Leaves, 5-8½" long and 1-1¾" wide, elliptical to somewhat lanceolate, long acuminate, base rounded to truncate, sometimes a little obtuse. Leaf margin almost entire, teeth reduced to small bristles. Both surfaces light green in color, the upper somewhat shining, glabrous. 19-24 pairs of veins were found on the specimens in Hamden, while Rehder (93) gives the figure 12-16, glabrous above and with a few appressed hairs below.

Buds ovoid in shape and pointed, reddish to reddish brown in color. With a few short appressed hairs, somewhat divergent. Phyllotaxy 1/2.

Flowers have only developed once on the specimens in the Hamden plantation (according to the pollination sheets) when, in 1943, a six year old plant received from Mr. Ching, China, bloomed with male as well as female flowers. Pollination was carried out July the second to July the eighth, which seems to indicate that the blooming falls comparatively late in the season.

Burs about 3/4" across with slightly pubescent spines. borne two or three together on a short spike.

Nuts* solitary or seldom two in the bur, globose, ovoid, pointed, 1/2-3/4" high.

* Based entirely on the description by Sargent (94) and Rehder (93)

The European Chestnut Castanea sativa Mill.

At present the European Chestnut is found over the entire southern Europe from Spain through southern France, Italy, Yugoslavia, Greece to Asia Minor in the east. It is however hard to separate areas with spontaneous occurence of the species from areas in which it has been introduced and is found now under wild conditions. Prof. Kai Gram of The Royal Veterinary and Agricultural College of Copenhagen gave in his lectures in Copenhagen the native home of the species as the mountains in the northern part of Asia Minor and Armenia, with a smaller area in middle Roumania.

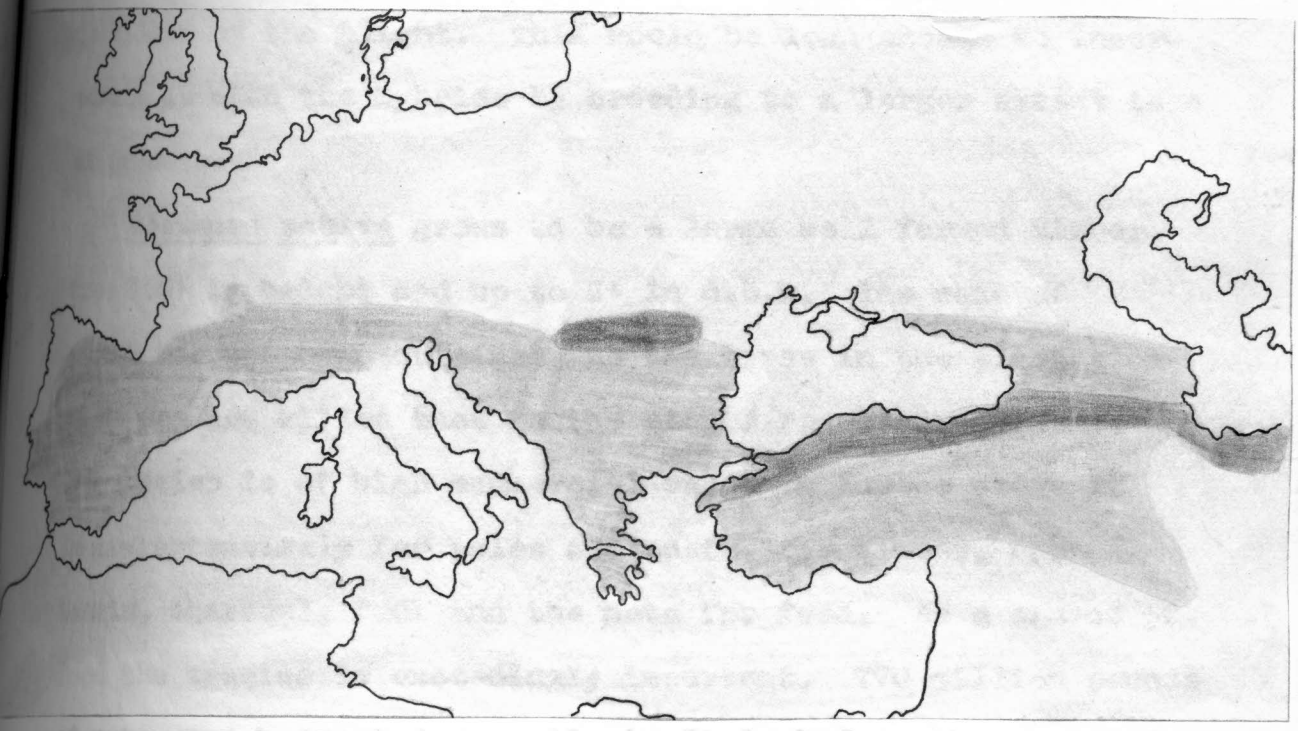

Figure #5.

Range of Castanea sativa
From Prof. Kai Gram, Copenhagen (Lectures)

native home

introduced, now growing under wild conditions

So far the introduction in Connecticut has been without success. Two examples are, however, known to the writer where the species has been grown in Denmark and developed to large trees. The winter temperatures in Denmark are much like those

in Connecticut with occasional drops down to -20°F, and zero weather not at all uncommon. To the writer this is an indication that it should be possible to introduce the European chestnut in Connecticut and at least keep it alive until it is killed by the blight. This would be long enough to incorporate it with the hybrids by breeding to a larger extent than at present.

Castanea sativa grows to be a large well formed timber tree 100' in height and up to 6' in d.b.h. The rate of growth has not been obtained, as the trees in the plantation in Hamden are killed back to the ground regularly by cold. The species is of high commercial value in Europe where it is used extensively for poles and posts, for timber, for tannin, charcoal, fuel and the nuts for food. As a source of food the species is exceedingly important. 770 million pounds of nuts were harvested annually in Italy before the war, and during the war the Italian population often had to rely solely on chestnut flour as food for weeks at a time. (108).

Botanical features:

Branchlets stout with slender ridges; soon glabrous but with a sandpapery surface. Young branches greyish brown, later turning to dark brown. Thicker branches dark brown with a rough surface. Lenticels light colored, not very abundant.

Leaves 5-8" long 1½-2" wide; elliptical to obovate; apex short acuminate, base acute to rounded, symmetrical or slightly asymmetrical; serration coarse. Lower surface short-pubescent especially along the nerves; upper surface dark green somewhat shiny; 16-18 pairs of veins with hairs and glands below and a

few glands above.

Buds very large, ovoid, with acute point. Inner budscales with tiny white hairs, light in color, somewhat reddish. Outer budscales extend only about half way up the bud and are of a dark brown color. Phyllotaxy 1/2 or 2/5.

Flowers have not developed on the specimens and only in a few cases has the species been used in the breeding work in Hamden and then always as imported pollen. It is thus impossible for the writer to state when the tree comes into bearing or when the blooming occurs.

Burs open in 4 valves. Further information is not available.

Nuts very large up to nearly 2" in diameter and somewhat less in height. (19). 2-3 in the bur. Hilum covers the entire base of the nut. Dark brown in color only with a few hairs near the apex. It is generally supposed that the original C. sativa had small nuts like those of C. dentata and that the large size is the result of selection.

The Alleghany Chimquapin Castanea pumila (L.) Mill.

The distribution of the chimquapin is from southern Pennsylvania and southern New Jersey to northern Florida in the Gulf States west to Neches River in the eastern Texas, and from Oklahoma and Arkansas to southwestern Missouri. (73.76). Sargent (95) says that in Arkansas, southern Missouri and Oklahoma, it is replaced by C. ozarkensis. In the Appalachian Mountains it grows at altitudes up to 4500'. The largest

size is reached in the eastern part of Texas and in Arkansas.

C. pumila is a shrub or a small tree, seldom more than 10'-15' high and 6"-18" in diameter. When the tree form is attained it has a short straight trunk, with a spreading crown. In the southern states it occasionally reaches a height of up to 50', with a diameter of 2-3'.

The wood is of a quality, very much resembling that of the American chestnut, and it is to a small extent used for fence posts, rails, furniture and railroad ties. (73). The nuts are a source of food for many small game animals. (76).

Botanical features:

Branchlets short pubescent to tomentose. Present year's growth grey to greyish-brown; previous year's growth dark brown and somewhat shiny; numerous small lenticels, but not of conspicuous color; older bark reddish brown, slightly furrowed and broken up in loose plate-like scales.

Leaves 3-5" long and 1-2" wide, elliptical to oblong-lanceolate. Apex acute or slightly acuminate, base broad cuneate, through acute to rounded, asymmetrical or symmetrical. Dense white felted-tomentose beneath, without glands; upper surface glabrous and shiny light-green; serration coarse; 19-20 pairs of veins tomentose below and glabrous above.

Buds short pubescent and fairly large. One of the outer budscales does not fit closely to the bud, but projects slightly giving the bud a pointed appearance; apex of outer budscales dark brown, becoming lighter reddish brown closer to the base. Pubescent. Somewhat divergent. Phyllotaxy 1/2.

Flowers develop early. Specimens planted in 1936 in Hamden were used for the breeding work in 1940 when they were four years old. The blooming takes place between June 20th and July 10th in Hamden. Coker and Totten (29) mention May 25 - July 3 in North Carolina. Unisexual catkins 4"-6" long, bisexual catkins 3-4" long, silvery tomentose.

Bur found two together at the base of the catkin near the apex of the flowering branch; spherical about 1" in diameter. Spines short pubescent near the base, turning red as the fruit ripens; opens in 2 valves.

Nuts solitary (seldom 2 in a bur), ovoid in shape and pointed. Tomentose near the tip; grey brown in color near apex, dark brown and shiny further down; pericarp very thick and hard to cut with knife. Seed testa long pubescent. About .4" wide and a little over 1/2" long. Taste, a little bitter.

The Ozark Chinquapin Castanea ozarkensis Ashe.

Green (73) gives the distribution of this species as follows:"Arkansas (north of the Arkansas River from Center Ridge) to southwestern Missouri (and westward to the valley of the White River); Arkansas and Oklahoma (Rich Mountain)". Harrar & Harrar (76) describe this chinquapin's range as follows: "The Ozark-Ouachita plateau in southern Missouri, Oklahoma, Louisiana and Mississippi, and on the adjacent coastal plains." Sargent (95) follows the first mentioned description.

Castanea ozarkensis is a comparatively small tree, with a maximum height of about 60'. The form is that of a forest

tree. Six trees measured in the plantation in Hamden showed an average mean annual height groth of 0.91'. The range was .75-1.08', the age was 12 years.

The species is of little commercial importance.

Botanical features:

Branchlets with a few scattered white hairs (this in October, probably more pubescent earlier in the season). Bark on present year's growth light grey in color, darker stripes visible with a hand lens. Previous year's growth of a dark brownish color. Ridges common on fast growing shoots. Lenticels not conspicuous.

Leaves 4-8" long and 2-2½" wide, elliptical to oblong-lanceolate in shape, with yellowish-green tomentum on lower surface, no glands. Upper surface light dull green; apex short acuminate; base from cuneate through rounded to slightly subcordate, mostly somewhat asymmetrical; serrations very coarse; 16-23 pairs of veins, glabrous above and with a few hairs below.

Buds fairly large, somewhat tomentose or short pubescent near apex; the two outer budscales of a characteristic shiny reddish brown color; broad ovoid in shape and blunt; somewhat divergent; phyllotaxy 1/2.

Flowers: No notes are available in the pollination sheets as to the age required before the trees begin to bear,or at what time in the season the blooming occurs. Male catkins 4⅝-6" long. (96).

Burs about 3/4"-1" wide, densely covered with spines.

Nuts borne solitary in the bur. About .6" high.

The Ashe Chinquapin Castanea ashei

The range is from northeastern North Carolina on the coastal plains to northern Florida and along the Gulf to Texas. (29.73.35.76).

It is a small tree or shrub; on Myrtle Beach in South Carolina a tree 27' high and 10⅜" in diameter has been found.

Botanical features:

Branchlets when young densely covered with yellowish-grey tomentum. Later in the season lower part of present year's growth glabrous or nearly so; older bark dark and smooth; lenticels somewhat lighter in color than the rest of the bark, present in great numbers.

Leaves 4-5" long, 1½-2" wide; obovate to elliptical in shape; apex short acuminate or acute; base acute to rounded, symmetrical or nearly so. Lower surface with greenish white tomentum; upper surface dark green and shiny. Serration coarse. 14-18 pairs of veins, short pubescent above, tomentose beneath.

Buds small, with short grey hairs; ovoid in shape, pointed. As they ripen, the color becomes dark grey-brown. Phyllotaxy 1/2.

Flowers: Specimens which were planted in Hamden in 1931, were used for the first time in the breeding-work in 1942, which seems to indicate that flowering occurs comparatively late in the life of the plant. The blooming falls from about June 27th to July 7-8th. No references give a description of the flowers.

Burs solitary or two together along the present year's growth. Characteristic of the bur are the short rigid spines projecting from the valves in small bundles, leaving bald spots in between. Spherical from .3" to .5" in diameter.

Nuts solitary, onion-shaped, about 1/4" in diameter; apparently of a high tannin content.

The Dwarf Chinquapin Castanea alnifolia Nutt.

The dwarf chinquapin is found from Georgia through Florida to Louisiana, according to Rehder (93). Coker and Totten (29) mention it in North and South Carolina also.

The species is without any commercial importance, being a low shrub.

Characteristic of the species is the ability to propagate by means of underground stoloniferous stems or "runners".

Botanical features:

Branchlets with dense yellowish grey tomentum as long as they are young. Gradually the tomentum is lost and the bark becomes dark brown and smooth. Lenticels present, yellow in color, but not conspicuous. Twig scar above pseudoterminal bud very large.

Leaves 3-4½" long, 3/4-1¼" wide; oblong to obovate in shape; apex acuminate, base acute to obtuse, symmetrical or slightly asymmetrical; lower surface with dense white tomentum, upper surface shiny light green. Serration rather fine; petiole dense short-pubescent; 19-20 pairs of veins, short pubescent on upper surface, white tomentose beneath.

Buds rather slender compared with other species, completely covered with grey tomentum. CColor grey-brown. Phyllotaxy 1/2.

Burs not borne at the extreme end of the flowering branch but 4-5" from the end, 3-5 together at the base of bisexual catkins; spines rather soft and not dense at the base of the bur so that the valve itself can be seen. Valve with white tomentum. Burs spherical in shape, ½-⅝" in diameter.

Nut solitary, conical in shape, about as wide as high, pointed and with tomentum near apex. About .3" in diameter.

Castanea margaretta = Castanea floridana margaretta Ashe

Green (73) gives the following distribution for this species: "North-central Alabama (possibly also extending into northeastern Georgia) and northeastern Texas to central southern Arkansas."

Castanea margaretta is a small shrub, without any commercial value.

Botanical features:

Branchlets short pubescent to tomentose. Bright red in color when young; becomes dark brown as ripening progresses. With many minute lenticels of yellowish color. Often two periods of growth in one summer.

Leaves elliptical to oblong-lanceolate. Apex short acuminate, base rounded or slightly obtuse, symmetrical or asymmetrical, lower surface with white tomentum. Upper surface glabrous and shiny dark green. Uniform coarse serration. 13-17 pairs of veins, glabrous or nearly so above, densely short pubescent beneath. Petioles short reddish, and tomentose. Sti-

pules persistent for some time.

Buds very small, conical in shape, short pubescent, greenish to light brown in color; somewhat divergent; phyllotaxy 1/2.

The specimens in Hamden are repeatedly killed back by the frost, with the result that no data are available with regard to flowers and fruits.

II HYBRIDS

Japanese Parents.

The earliest breeding work carried out by Dr. Graves, was, as stated in the introduction, done on Long Island, where he found several large Japanese chestnut trees, which had resisted the blight. Before a further description is given of these early hybrids it may be of interest, shortly to describe the trees with which he worked.

RT 107 N 1 mi. S of 25A

1. *Paul Hammond, Syosset, Long Island. This tree, which is the female parent of Hammond--86 described below one of the best Japanese-American hybrids is apparently of pure Japanese stock. (Graves 52). It is a grafted tree with two leaders which differ a little from each other, one bearing a single, the other three nuts in each bur. The tree is growing well although it is attacked by blight in several places. (52).

called "Spanish"

corner (NW town) Mill River Rd. & Locust Valley-Oyster Bay Rd.

2. Renville S. Smith, Oyster Bay, Long Island. Graves (52) mentions this tree as "evidently of hybrid nature". It was, in 1929, 35 years old and 1' in d.b.h. and had a spread of about thirty feet. It bore only one nut in each bur. The tree had the blight, but many cankers had been healed over.

Locust Valley

3. Minturn, Oyster Bay, Long Island. Dr. Graves describes this tree as tall and with a single stem; disease resistant; it looks mostly like the Japanese chestnut, but may have a small amount of C. sativa mixed in.

* The trees have been named after the owner of the estate where they were found.

East Norwich

4. Winthrop, Westbury, Long Island. This tree was in 1929 6" in d.b.h., 25-30' high and had a spread of 45 feet. The leaves are a little longer than those commonly found on C.crenata and there may be some admixture of the European chestnut. There is one completely healed lesion on the trunk, but fresh cankers are found here and there on the branches. (52).

Castanea crenata x Castanea dentata

South Lot R4T10
9ft. R4T3

Botanical description of Hammond 86 '31 C.crenata x C. dentata

Branchlets glabrous even when young, present year's growth greenish-yellowish-brown, previous year's growth dark grey-brown. The older bark on the stem remains smooth for a long time and resembles very much the bark of C. dentata. Lenticels of light color but small.

Leaves 5-8" long 1¾ - 2½" wide, elliptical to obovate in shape. Apex long acuminate, base acute to rounded or slightly subcordate, symmetrical or slightly asymmetrical. Serration somewhat varied, but mostly fine as that of C. crenata. Lower surface glabrous light green. Upper surface shiny light green. 17-21 pairs of veins, pubescent above and beneath.

Buds glabrous or nearly so. Fairly small, ovoid in shape, of a yellowish-brown color. Apex blunt, somewhat divergent. Phyllotaxy 1/2 or 2/5.

Flowers. Hammond 86-31 was used for the first time in the breeding work in 1936, in other words it probably bloomed for the first time, when it was 5 years old. Other hybrids of the same conbination, but with different parents (was Renville Smith Jap.) bloomed already, when they were 3 years old, which

is early for the chestnuts and a sure sign of hybrid vigor. The blooming starts about June 19th in early seasons and ends about July 17th in the late seasons. As to the characteristics of the flowers no data are available.

Bur: The bur is large about 3" in diameter. Outer surface short pubescent and with long rigid and glabrous spines. In most cases, it opens readily in 4 valves, inner surface dense long silky hairy as C. dentata. It is one of the latest trees to ripen in the plantation, the nuts being shed October 15th-20th.

Nut large about 1¼" in diameter and 1-1/8" in height. It is very similar to the American chestnut in color, maybe somewhat lighter,and it has the same tomentum covering almost the entire surface. The hilum covers the entire base. Seed testa easy to remove. The taste is fairly good, although it is not as sweet as the American.

The tree has, except for the shape of the leaves, entirely American features. This is, however, not always true with other individuals with the same combination, but a different pedigree. 26 trees were examined for dominance and of these, 16 trees had the American father as the dominant, while 10 trees showed Japanese dominance. There is no clearcut line as regards dominance, however, and in many cases it is difficult to decide in which group the trees should be placed.

Hammond 86-'31 has inherited the good growth form of the American chestnut, as have most of the Japanese-American hybrids. Of 27 individuals, 21 were of a good or fairly good form and only 6 were described as spreading. In general the

hybrid shows a definite hybrid vigor, the mean annual height growth of 17 trees was 1.23', with a range from .35' to 2.04'. Most regular and pronounced is it for the trees with Paul Hammond Jap as female parent, of the three trees of this pedigree still living in the plantation the average MAI in height is 1.81', with the range of 1.69-1.94'. Only one tree with Minturn Jap as parent is still living, this shows 2.04' for the same figure. The Smith hybrids on the other hand show no heterosis at all with regard to growth rate, the average for 4 trees is .82' or about the same as for C. dentata.

The Japanese-American hybrid thus has several good features, but it soon proved to be only a little more resistant to the blight than the American and only repeated inarching has made it possible to keep the trees alive until now. It is however still one of the most important hybrids ever developed at the plantation, because it may be possible to obtain higher resistance and still maintain the good form by further crossing with C. mollissima.

If it should prove to be possible to propagate chestnut vegetatively at a reasonable cost, there may be a future for the growing of chestnut fence posts in this way on a very short rotation. Grafts have been made of Hammond 86 which shows very fast growth; the oldest one now 10 years old is 28½' high, one graft only 2 years old is 13' high. With growth rates like that it would be possible to obtain fence posts on a 10-15 year's rotation. The grafting of the chestnut is, however, at present

so difficult that more experimental research is required before such production could be taken up on a commercial scale.

Castanea mollissima x Castanea dentata

The first hybrid with this pedigree was made in 1934. Here, as in the Japanese-American hybrid, it was hoped that by crossing the highly resistant but spreading C. mollissima with the susceptible but well formed C. dentata a well-formed and resistant hybrid eventually would develop.

In all instances trees of pure Chinese blood have been used; most of them imported directly from China by the United States Department of Agriculture or Dr. Graves, and only a few were received from various sources in the states.

Also in this hybrid due probably to heterozygous parents, the offspring vary greatly. Of 28 individuals examined, 17 showed various degrees of Chinese dominance, while 11 showed American dominance. One individual of each group will be described and they will be numbered I and II respectively.

I. Botanical features of C. mollissima x C. dentata 62-'35

Branchlets with long soft divergent yellow hairs. Present year's growth yellowish-grey in color; previous year's growth dark brown; older bark very similar to C. mollissima, dark somewhat shiny soon becoming furrowed; lenticels whiter in color than on Chinese chestnut, fairly large.

Leaves oblong to elliptical in shape; 5-6" long, 1½ - 1⅝" wide; apex short acuminate, base acute to rounded. Serration coarse; lower surface shiny light green; 14-17 pairs of

veins, hairy on both surfaces. Petiole pubescent. In other words they are somewhere in between the Chinese and the American chestnut.

Buds ovoid in shape, slightly pointed, densely covered with short hairs. Younger buds yellowish grey in color, later grey brown. Somewhat divergent. Phyllotaxy 1/2.

Flowers: This hybrid was first used for further breeding in 1939, when the trees were 5 years old. The blooming falls rather late; of all pollinations in which the hybrid was used, the earliest was started June 27th and the latest finished July 18th. No data are available concerning the characteristics of the flowers.

86-34 R4T5 ?

Burs about 2¼ - 2½" in diameter when full grown. Pubescent on outer surface, densely covered with rigid hairy spines. Spines somewhat shorter and stouter than those on American chestnut. Inner surface densely silky hairy.

Nuts about 3/4" wide and slightly higher. Covered with tomentum from a little below the middle to the apex. The hilum covers the entire base of the nut. Seed testa easy to remove. Of a good and sweet taste.

II. Botanical features of C.mollissima x C. dentata 523 -'35

Branchlets short hairy when young, later in the season they become glabrous or nearly so. Of a rich somewhat reddish brown color where exposed to light, brown-greenish beneath. Older bark very similar to that on American chestnut. Lenticels present but small.

Leaves elliptical to oblanceolate; 8-9" long, 2-2⅝" wide;

apex long acuminate, base cuneate to acute. Lower surface short and not very densely pubescent; upper surface light green and somewhat dull. Serration coarse. 18-21 pairs of veins, pubescent on both surfaces.

Buds fairly large, conical in shape and pointed. Short hairy especially towards the apex. Yellowish-brown, darker towards the apex. Somewhat divergent. Phyllotaxy 1/2.

So far only a few good trees have been developed of this genotype. The best is now 12 years old, 22' high, and has a good form. It is being attacked by the blight, but shows resistance. The other individuals do not show any outstanding features. The average mean annual height growth of 23 trees was .96' with a range from .19' to 1.83'. The trees were from 8-13 years old. This growth rate equals that of C. mollissima and so the hybrid does not show any hybrid vigor on an average.

15 out of 28 trees were spreading, the rest of good or fairly good form. With regard toblight many of the trees are fairly young and can be expected to be attacked in the near future. 30 trees were examined for blight; of these 7 had been killed and 7 were attacked by the blight, but showed various degrees of resistance. These two groups include all but two of the trees older than 10 years. 16 trees had not been attacked at all up to the present time.

The hybrid is, however, not at all unimportant, and good results may be obtained by further crossing of selected individuals of this combination with other more resistant and well-formed stock.

The reciprocal cross C. dentata x C. mollissima shows features which are very much like those of C. mollissima and C. dentata, I. Perhaps the American chestnut gives a slightly higher degree of dominance here.

Castanea mollissima x Castanea seguinii

The breeding of a timber type resistant chestnut has been the first consideration in the hybridization work. This hybrid, however, is an example of breeding with the development of a good orchard tree in mind. Both parents have a nut of good taste and the hope was that the hybrid would combine the good taste with the prolific production of nuts, characteristic of the Chinese chinquapin.

Botanical features of Castanea mollissima x C. seguinii, 17A-34

R12T6

Branchlets short pubescent; present year's growth yellowish-brown-grey; previous year's growth grey brown, glabrous or nearly so; lenticels present but not of conspicuous color.

Leaves 5-6½" long and 1⅝"-2½" wide, elliptical to obovate. Apex short acuminate; base acute through rounded to slightly subcordate; serration rather fine; lower surface covered with dense tomentum, upper surface shiny dark brown; 16-18 pairs of veins, pubescent on both surfaces.

Buds of medium size. With short pubescense, ovoid in shape with slightly pointed apex. Younger buds light greyish brown, older buds with shiny light-reddish-brown, outer budscales, which does not extend to the tip. Somewhat divergent. Phyllotaxy 1/2.

Flowers: This hybrid bore flowers for the first time in 1937, when it was used for further breeding work. The plants were then 3 years old, an early age for flowers. June 22nd is the earliest date on which the pollination has been started, and July 14th is the end of the flowering period. No data are available referring to the characteristics of the flowers.

Burs: The burs are densely covered with long short-hairy spines. The bur opens readily in 4 valves. Along the seams of the valves are two rows, one on each side of flattened solitary spines. Burs spherical, 2-2½" in diameter.

Nuts usually 3 in the bur, brown with darker stripes with short hairs especially towards the apex. About 3/4" wide and somewhat longer. Seed testa easy to remove. Of all the nuts examined from different species and hybrids, this was judged by the writer to be the best. The meat is very sweet and good in taste, and the texture fine. Ripening varies with the different trees, but falls between October 7th and 20th.

Another tree in the plantation with the same pedigree (17-'34), a sib of the tree just mentioned, shows features which are even more characteristic of C. mollissima. The branchlets have the common long divergent yellow hairs. The leaves are broad like those of the Chinese chestnut and have the almost truncate base. Also the nuts resemble those of C. mollissima closely, although they are somewhat smaller.

As could be expected, the 4 trees examined are all of the spreading type, nor do they show any particular rapidity of growth. Only one of three trees is attacked by the blight,

and this tree shows a high degree of resistance. One of the trees may be somewhat more prolific than the Chinese (good nuts, also) and on another the nut is excellent, but the tree is not prolific at all; in other words the first class orchard tree has not been developed yet,but the results are promising and it is still believed that further breeding of C. mollissima and C. seguinii could give an excellent orchard tree.

C. crenata x (C. crenata x C. dentata)

This cross was made for the first time in 1935, the object being to bring more Japanese stock into the Japanese-American hybrid, and by so doing increase its resistance to the blight.

Botanical features of C. crenata R13T2 x (C. crenata Hammond x C. dentata) R51T42 88-'42

Branchlets with short divergent hairs; color of the present year's growth reddish when exposed to light, greenish beneath; previous year's growth dark brown, resembling the bark of the Japanese chestnut very closely; lenticels fairly small, white in color.

Leaves oblong or lanceolate, 5"-6" long, 1½"-1⅝" wide; apex long acuminate, base acute through rounded to slightly truncate or subcordate; serration rather fine, teeth long. Lower surface densely covered with yellowish glands; upper surface light green. 20-23 pairs of veins, pubescent on both surfaces.

Buds medium size,ovoid in shape, slightly pointed. Short hairy outer budscales, which do not extend to the apex, usually with sections of different color, nearest to the base red, next

yellowish and finally dark brown; apex of the bud yellowish; somewhat divergent. Phyllotaxy 1/2.

Flowers occurred for the first time in 1940, when the trees, from pollinations in 1937, and thus being in their fifth year of growth were used for further breeding. The blooming falls early; June 19th is the earliest date on which pollen has been used, and July 10th, the latest date on which female flowers have been pollinated.

Burs: short pubescent on the outher surface; densely covered with long rigid spines; spines glabrous or nearly so; inner surface sparsely silky hairy; open fairly readily into three or four valves. Spherical, about 2½" in diameter.

Nuts sometimes shed while they are still white near the bases. Light brown in color, with short hairs especially toward the apex. About as wide as they are high, 15/16"-1" in diameter. Seed testa hard to remove; in taste with a slight tannin content.

The described tree shows, as can be seen, definite Japanese dominance, this also holds true with all the 31 trees of this pedigree examined. About one half of the trees (16) are of the spreading type, while the other half (14) hada good (6) or a fairly good form (8). With regard to resistance to the blight it is yet too early to get an impression of the true situation, because the greater part of the trees are only 7 years or younger. Of 30 trees examined, 1, and it is important to notice that this was the oldest tree, now 12 years old, was killed by the blight. One tree was attacked by the blight,

but showed resistance. The rest, 28 trees in all, were not attacked by the blight. But knowing the only partial resistance of the Japanese parent, it must be expected that the greater part of these trees will be attacked by the blight, if not killed sooner or later.

The hybrid shows definite hybrid vigor, the average mean annual height growth of 36 trees was 1.20" with a range from .60' - 2.31".

The reciprocal cross (C. crenata x C. dentata)x C. crenata is very much like the above described. The Japanese parent is dominant. The form does not seem to be quite so good, as in J x JA. What has just been said with regard to blight also holds true in this case. The growth rate, however, is smaller, and the hybrid shows no heterosis on an average. The average for 21 trees was 1.01' per year.

(Castanea Smith crenata x Castanea dentata) x C. dentata 2 nuts 1934 1 nut 1935

The desire to develop a good timber tree, was the reason for this early (1934) crosswhile the low degree of resistance in the Japanese-American hybrid still was unknown. The results were far from good, all the older trees now being dead, and only sprouts remaining.

Botanical features of (C. crenata x C. dentata) x C. dentata
21A-34 South Lot R5T9 gone by 1963

Branchlets glabrous or nearly so. Present year's growth greyish brown, on sprouts reddish. Previous year's growth with brown bark. Few very small white lenticels.

Leaves elliptical to oblong; 6½-10" long, 1¾-2½" wide; apex long acuminate, base cuneate to acute; serration irregular, some leaves coarsely serrated; some sinuated and with small bristles; lower surface appears to be glabrous, but under a hand lens minute glands can be seen, especially along and on the nerves of the lower half of the leaf. Upper surface green and rather dull; 21-25 pairs of veins, with scattered hairs on both surfaces.

Buds large oblong in shape, apex blunt; nearly or quite glabrous. Outer budscales, which do not extend to the apex, brown towards the end, base and apex of bud lighter brown; somewhat divergent. Phyllotaxy 1/2.

Flowers. The hybrid has been used once in the breeding, in 1940, when it was in its sixth year of growth. In other words the first flowers develop somewhat later in the life of the tree than on the Japanese chestnut, but before the American. 1940 was a year of late blooming, the first pollination not starting until June 28th. There is however, no doubt that the hybrid blooms late in the season. In the year mentioned, it was used in breeding between July 18th and July 23rd.

The two older hybrids of this combination have already been killed to the ground as mentioned above while two now 9 years old, so far have remained untouched by the blight; the writer, however, feels certain that they will succumb shortly. All trees show American dominance. The two unblighted trees have a spreading form, and show a growth rate of only .50' and .89' per year.

The reciprocal cross C. dentata x (C. crenata x C. dentata) does not differ from the one just described. The American features are dominant, the largest trees are only 4 years old, and are killed by the blight. The growth rate however is rather good, although not heterotic the average of 4 trees being .96' per year.

Castanea dentata x S. 8

Before a description is given of this hybrid it may be well to mention S.8 shortly. It has already in the introduction been stated that S.8 was developed by Walter van Fleet sometime between 1894-1911. What the exact pedigree of this hybrid is, has always, however, been in doubt, because van Fleet did not keep complete records. In the literature it is sometimes mentioned as C. mollissima x C. pumila as well as C. crenata x C. pumila. Van Fleet mentions in in an article in Journal of Heredity 1914 a hybrid C. pumila x C. crenata, which he describes somewhat as follows:

A vigorous small tree, which bloomswhen it is 3-5 years old. Burs are born in clusters of 3-5 as on chinquapin, rarely solitary. Contains 1-3 nuts of the chestnut type, but 4-6 times as large as that of C. pumila. The tree blooms profusely and ripens very early, the first burs opening in late August and they are fully mature by October. The nut is dark brown and smooth with only very slight tomentum, sweet and without tannin flavor or bitterness in the inner skin. The second year the leaves segregate into the pumila type with

slight light tomentum and that of chestnut larger and clear green on both sides. The segragation is accompanied with the characteristic branching of the respective types.

With regard to the parents of the hybrids, he says that the C. pumila was "a particularly protective and precocious plant grown from seed collected in 1889 in Virginia." The parent of the best hybrid, were with a few exceptions, home raised varieties of C. crenata, and quite likely are hybrids themselves with our native chestnut.

The question is then, is S-8 one of the hybrids here described?

Twice the same cross has been attempted on the Hamden plantation, using pure stock for both parents, but without result. The reciprocal cross did, however, give results in two years, and the conclusion may therefore be correct that S-8 = C. crenata x C. pumila. Trials in two different years and only a few bags (2 in 1941 and no records 1942) do not prove, however, that the pollen is incompatible and it is possible that the pollen of the "varieties" used by van Fleet had other qualities than the pure stock, which was used at Hamden. That S-8 = C. mollissima x C. pumila seems doubtful, for C. mollissima is late in blooming (starts about the 27th of June), while C. pumila starts early -- about the 20th of June. There is some overlapping, but it seems unlikely that van Fleet should have made the cross in this short period. Another important point is, that van Fleet, according to his own article (40), did not use C. mollissima before 1911. Fi-

nally, S-8 does not show any features which resemble the Chinese chestnut.

The conclusion seems to be, that until it is definitely proved that pollen of C. crenata is incompatible with C. pumila, S-8 must stand as C. pumila x C. crenata.

The purpose of the cross C. dentata x S-8 has not been mentioned anywhere, but in his report for 1937 (59), Dr. Graves says concerning the reciprocal cross "a pollination of S-8 with a good American parent is very desirable, in order to give offspring with a greater height growth."

Botanical features of Castanea dentata x S-8 60A - '35 south lot R8T9 dead

Branchlets with only very few hairs in October, probably more pubescent earlier in the season. Where exposed to light rich reddish-brown in color, greenish brown beneath, older bark resembles that of C. dentata very much. Lenticels present in a large number, but rather inconspicuous.

Leaves 6"-9" long, 1½ - 2½" wide, elliptical to obovate; apex long acuminate, base cuneate to acute; serration coarse; lower surface with dense greenish white tomentum and no glands; upper surface shiny light green; 18-21 pairs of veins, somewhat hairy on both surfaces.

Buds large, ovoid, sometimes slightly pointed; with short hairs towards apex; outer budscales, which extend about 3/4 of the way up the bud, shiny and reddish brown; phyllotaxy 2/5.

Flowers were developed for the first time at Hamden plantation in 1938, when the plants were in their third summer.

The blooming period occurs usually from about June 29th and July 13th.

Burs about 1⅜ - 2" in diameter, densely covered with very rigid long spines. Spines somewhat short hairy. Flattened spines along the seams, rigid; Bur opens readily with 4 valves, and sheds the nuts while still on the tree.

Nuts about as wide as they are high. 7/8" in diameter. Usually 3 in the bur; light brown in color with long hairs especially towards the apex; a large part of the style remains on the nut and gives it a long pointed appearance; of a rather good taste, maybe with a little tannin content.

The American mother seems to be dominant in this hybrid. The tree described here has a fairly good growth form and a fast growth, 1.75' per year. One other individual resembles it closely (growth rate 1.58' per year), and one comes closer to C. pumila being a small tree of slow growth. (.75' per year) and a spreading form. One of four trees has been killed by the blight, and the three others are all attacked, but show some resistance.

The reciprocal cross does not show as strong a heterosis as the above, the average for 4 trees is .98' with a range from .67' to 1.25' per year. They are all spreading. As to blight, the conditions are as follow: One tree killed, one not attacked yet, 3 attacked but showing various degrees of resistance.

Castanea mollissima x (Castanea crenata x Castanea dentata)

When it was realized that the Japanese-American hybrid did not possess the desired resistance to the blight, but in other ways had very good characters, it was crossed with the highly resistant Chinese stock. The hope was that it would retain the good form and fast growth of the Japanese-American parent and, at the same time, obtain more resistance from C. mollissima.

Botanical features of C. mollissima x (C. crenata x C. dentata). 545-'38

Branchlets with long divergent yellow hairs; present year's growth yellowish-grey, previous year's growth dark-brown somewhat shiny; older bark soon becoming furrowed as on the Chinese chestnut; leaf base raised from the branch at a sharp angle; many large lenticels of whitish color.

Leaves 7-8½" long, 2½-3" wide, elliptical to oblong; apex short acuminate; base acute to rounded. Serration coarse, lower surface short tomentose, upper surface shiny green; 17-20 pairs of veins, pubescent on both surfaces.

Buds ovoid in shape, apex pointed; short, hairy; light greyish-brown in color; somewhat divergent; phyllotaxy 1/2.

Flowers: Further hybridization was carried on with this hybrid in 1943 when a seedling from 1938 was used, the plant being in its fifth year of growth. The hybrid has inherited the late blooming from its mother parent; it falls between June 30th and July 11th.

No records were taken of the characters of the burs and nuts. The burs, however, are large and resemble superficially the Chinese bur; also the nuts are much like those of

C. mollissima.

An other individual (545-38) of the same combination can be described as follows:

Branchlets: With long divergent yellow hairs; color of present year's growth yellowish-grey; color of last year's growth, dark golden-brown to grey-brown; with many light colored fairly large lenticels.

Leaves, 6-8" long, 2-3" wide; elliptical to ovate; apex fairly long acuminate, base acute to rounded. Serration coarse; lower surface with dense whitish-green tomentum; upper surface shiny dark green. 15-18 pairs of veins, short pubescent on both surfaces.

Buds ovoid, with somewhat pointed apex; densely covered with grey hairs; greyish-brown in color; somewhat divergent; phyllotaxy 1/2.

It is clear that the two individuals, which here have been examined show a very definite dominance of the Chinese characteristics. The same holds true in far the greater part of the individuals with a similar pedigree. Of 61 trees recorded, 53 were noted as having dominant Chinese features, 1 showed American and 4 Japanese dominance. 3 were described as being of incomplete Chinese dominance.

Unfortunately the poor form of C. mollissima shows up in most of the trees. Of 61 individuals examined, 36 had a spreading growth form, 18 had a fairly good form and only 7 had a form which the writer considered good.

The fieldrecords concerning the blight resistance have been summarized in the table below.

Table #5 - Blight Resistance of C. mollissima x (C. crenata x C. dentata

Year of Pollination	Total No. of Trees	No. of Trees not Blighted	No. of Blighted, but Resistant Trees	No. of Trees Killed by the Blight
1937	27	17	8	2*
1938	24	16	7	1
1940	3	1	2	0-
1942	2	2	--	--
1943	1	1	--	--
Total	57	37	17	3

* One tree may not be killed by the blight.

Comments are hardly necessary; that the hybrids are resistant to the blight is beyond doubt. One thing, however, which does not appear in a table is the form of resistance. This is very much as in C. mollissima. Some cankers are completely healed; on some individuals the blight seems to be able to attack the outer bark only, and the rest of the trees show signs that they may only, if ever, succumb after several years of repeated attacks.

Finally, the growth rate must be mentioned, so The table

below is based on 55 trees measured in the fall of 1947.

Table #6 - Height growth of C. mollissima x (C. crenata x C. dentata

Year of Pollination	Total No. of Trees	Total Average Height Growth per Year	Average Height Growth per Year	Range
1937	26	32.23'	1.24'	.55'-2.00'
1938	22	26.29'	1.20'	.39'-1.83'
1940	3	4.29'	1.43'	.86'-1.86'
1942	3	2.20'	.73'	.40'-1.00'
1943	1	1.00'	1.00'	-----
	55	66.01'	1.20'	.39'-2.00'

The hybrid shows a definite hybrid vigor. It is believed that if more trees had been available from 1940, the figure would have been much lower, probably a little below 1.20', because the trees in general seem to grow slowly in the earlier years: fast growth does not start until the trees are 8-9 years old. Some of the 10 year old trees have grown about 5' in height annually in the last couple of years.

C. mollissima x (C. crenata x C. dentata)is the most promising hybrid growing in the plantation at present, and with further breeding and selections among the best offspring, it may be part of the answer to the problem of developing a disease-resistant timber chestnut.

SILVICULTURAL ASPECTS

I. Site requirements:

In choosing a site well suited for the growing of foreign or hybrid chestnut, it may be advisable first to consider the conditions under which the native American chestnut has its best development.

The American chestnut is less dependent on the chemical than on the physical condition of the soil.(10 and 109). Thus a fertile soil is not essential. As to what exactly it requires in this respect, opinions seem to differ. Zon (109) states that a soil with a moderate clay content (not enough to interfere with the looseness of the soil) together with some potassium and lime, suits the species best. Ashe (10) is of a somewhat different opinion; he says that it grows well on a sandy soil with a subsoil deficient in lime as well as potash. Two writers (4,12) go so far as to say that it is naturally adapted to poor, hilly land which is not suited for agriculture. The weakness and divergence of these statements can perhaps be taken as an indication of the small importance of the soil nutriment. One thing all the writers agree upon is that the chestnut does not grow on soils with a high lime content derived from limestone.

The soil porosity and moisture relation is very important. The soil must be porous permitting an easy penetration of the roots and of water. Heavy cold and wet clay soil are definitely unfavorable, while loams, sandy loams even sandy and gravelly

soils give a good development. Drainage conditions must be good; a high water table and wet soils should be avoided. The moisture requirements are moderate, it does not require quite as much as yellow poplar, but is more exacting than white oak, which replaces it on the drier soils.

Frost pockets should be avoided, and moderately cool, shady slopes or coves and elevated mountain benches chosen.

If then the Asiatic (there is only very little information regarding C. sativa) chestnuts are considered, it will be seen, that they in many respects are much like in others more exacting than C. dentata in their requirements. The soil must be fertile and deep, well drained, but with a good waterholding capacity. (81). Here as with the American chestnut a high water table is a very poor site. Hardpan or a heavy impermeable substrata must be avoided. (81).

Sites with accelerated erosion,(81), thin or worn out soils, and dry, grassy spots (34) are apt to be failures, while a top soil with a good layer of humus and litter, as found on a good forest site, is very beneficial.

With regard to the acidity of the soil Blake and Edgerton (19) say that it should not be less than a pH of 6. Gravatt and Fowler (47) state that the Asiatic chestnuts trive well at a pH of 7, but they do not thrive where the amount of alkali is too high.

Lime and dolomite in high amounts have been mentioned as unfavorable by Diller (35), while Schenck (96) says that C. mollissima according to Chinese information is found on limy

soils.

Finally, the indicator plants for a good chestnut site as given by Diller (35, 36) should be mentioned:

Trees: Yellowpoplar, Northern Red Oak, Cucumbertree Magnolia, Black and Yellow Birch, Sugar Maple.

Shrubs: Spice bush.

Herbaceous vegetation: Maidenhair fern, Bloodroot, Jack-in-the-pulpit, Squirrelcorn, Dutch-man's-breeches.

Sites with Broomsedge, Sumac, Hardpines and heavy sod indicate a poor chestnut site. A site too wet for the Asiatic chestnut is indicated by Black Ash, Red Maple, Willows and Alder.

Diller (35,81) recommends the planting on small-sized areas in the forest, which recently have been clearcut; or crown openings created by selective logging. Also, he says planting along the northern or eastern edges of woodlands, where the protection from temperature extremes is good, will give promising results.

The choice of a site with regard to air drainage must be made with care; frost pockets are definitely unsuitable. Gentle slopes or the tops of ridges (not rocky and dry) in rolling topography will be the best. (6). If possible northwestern and northern exposures should be preferred. The leafing will start later here and injury from late spring frost will be less frequent. (10).

II. The raising of chestnut seedlings.

It is impossible to establish a chestnut plantation by broadcast sowing or planting of the nuts. (35,73,96,100). The nuts would soon be destroyed by rodents or squirrels and only a few if any nuts would be left for germination. The only way is to plant out nursery stock. I shall therefore describe next the most successful ways to raise seedlings.

The easiest method may be described as follows:

After the nuts have been collected they are cured for a period of 5-10 days. This can best be done in an ordinary room, where they are protected from the sun. Thereafter, they are planted in pots in a mixture of 50% sand and 50% peat moss (percentages by volume); there should be a space of 1-2" between the nuts, and they must be covered with a layer of the mixture about 1/2" deep. The depth of cover depending upon the size of the nuts. Each pot has a wooden label giving the pedigree of the nuts.

The pots are placed in an open cold frame well protected with wirescreens from mice and squirrels, and left here until the middle of December, when they are covered with a thick layer of litter and heavy boards.

By the beginning of March the nuts will start to germinate and the boards and leaves are removed. When the plants are about 4" in height, they are carefully removed, each one labelled with its pedigree and year, and planted in the prepared beds. The method is simple and gives good results.

Another much more laborious and complicated method has been described by Galloway. (42).

After curing, the nuts are planted in flats and placed in a greenhouse, where the night temperature does not exceed 40°F. The nuts will start to germinate in January and as soon as they get a couple of leaves 5-6 plants are planted together in 6" pots. In the spring about the 10th-15th of May, they are finally planted with the ballsin the nursery beds.

A third possibility is to store the nuts until the next spring and plant them as early as possible.

The best way to store the nuts is to pack them in slightly moist sphagnum moss (4 ounces of water to one pound of dry moss) and store them at 32°-34°F. Too much water will spoil the nuts, but they must, on the other hand, not dry out. They can also be mixed with sand in a box protected against rodents and placed in the ground in a well-drained location. (5). Under these conditions the nuts tend to germinate very early, and they must be planted before this happens. (5, 102).

III. Planting:

The choice of the right time of planting, a good method of planting and careful execution of the job are exceedingly important as has been emphasized by Bedwell.(16). He found in many instances that while the failure of a plantation had been blamed on other agencies such as drought and winter injury, the damage actually was due to improper planting.

Spring planting is the one commonly used, and is, according to Graves, the one that gives the best results. He has tried fall planting in several instances, but never with much success. It is important that the planting is done before the drought sets in, in the spring, with a consequent lowering of the water table.

The best planting stock is 1-2 year old seedlings. (Diller 35). Later Diller (81) states that 1/1 transplants about 2' high give the best results. Blake & Edgerton (19) mention 2-3 year old, 2 to 3 feet high plants as good to plant in their permanent location.

The crowbar and split method of planting cannot be recommended, unless a skillful and careful laborer takes care to compact the soil around the roots. (16). Even then, the method can only be applied on the very best permeable soil. The best method is by the dug-holes. It has the following advantages: (1) one can make large holes, which is important on a clay soil; (26); (2) one can mix the subsoil with good top soil, which also is necessary under such conditions; and (3) good root position is more easily obtained, and will increase the chances of good results. (34).

Bedwell (16) has emphasized that the root collar must be placed in the proper position in the hole.

The spacing of the plants depends on the purpose for which they are planted and the price of the plants. A plantation in the open for the maximum nut production requires large spacing.

Originally, stock at Hamden was planted 15 x 15 feet, but now that the trees are 19 years old, they are crowding each other and should have been planted with a much larger spacing. Blake & Edgerton (19) recommend spacing of not less than 25 x 25 feet in an orchard planting.

In the forest where the main object is the good natural pruning a much closer spacing is necessary. The price of the planting stock is, however, such that a spacing closer than 8 x 8 or 10 x 10 feet would not be economical. (35). With a 10' x 10' spacing an opening in the forest 50' in diameter can accommodate 20 trees. In such an opening Diller (35) suggests the use of the pattern of planting showed in the figure below, because it makes it easier to find the individual plants again and keep records about them.

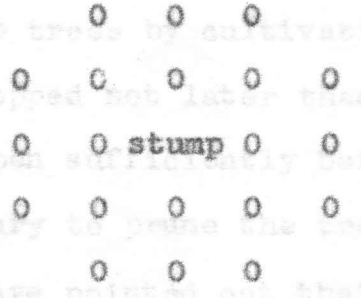

Figure #6, Asiatic chestnut "stump-planting" (spaced 8'x 8' or 10'x 10'). From Diller (35).

IV. Care of the young trees.

The trees are unable to compete with grass and weeds. In the forest cleaning and release cuttings must be carried out during the first 8 to 10 years of the life of the stand, then, when the crowns of the chestnuts are well above the

competing sprouts, the cleaning should stop and competition from the sides allowed in order that natural pruning may be most efficient. (34 & 35). The release cuttings must be undertaken during the winter or early spring, so that the shootripening is not delayed, nor the trees damaged by early fall frost. (31).

If the planting has been carried out under a full forest canopy, the overstorymust be girdled at the time of planting. The older trees willdie gradually and leave the site to the chestnut without disturbances of the ecological conditions of the area. (35 & 36). The method will, of course, give rise to some damage to the young seedlings, as the girdled trees deteriorate and fall down, but it will seldom exceed 25% of the trees. (34).

In an orchard planting competing grass and weeds must be kept away from the trees by cultivation. It is important that cultivation is stopped not later than in early August, so that the shoots can ripen sufficiently before the first frost. (6).

It is necessary to prune the trees to some extent. Blake & Edgerton (19) have pointed out that trees with large crotches close to the ground seem to be more susceptible to the blight than those, which have been pruned carefully. At Hamden, pruning of the older trees has been carried on to some extent, cutting out intermingled branches and the like. A somewhat different opinion is held by the Bureau of Plant Industry; (6); they recommend that pruning be limited to the training of the trees

to the desired form, and state that further pruning will only reduce the size of the trees and delay production. In the forest, pruning as it now is common practice in forestry, must be carried out, if natural pruning is not satisfactory. The best time for pruning is in the fall, when growth has ceased, in winter or in the early spring.

If the trees for some reason or other are killed back to the ground and send up several sprouts, all but one sprout should be removed, in order that they do not compete mutually. This can best be done, when the sprouts are about 4' high. (35).

In orchards it may be possible to do something to save trees which in spite of expected resistance to the blight have been badly attacked. Small branches can simply be cut off, but where cankers are found on the trunk it is necessary to cut the infected spots out. Care must be taken, that all infected bark is removed, and the edges of the wound must be sharply cut and clean. Rinsing the wound with a 1-1000 solution of corrosive sublimate in water or a 5% solution of formalin in water has been recommended by some authors.(7). All wounds must be covered with a good coat of coal tar, lead paint or shellac, to prevent new infections.

V. Application of fertilizer.

The application of fertilizer is common practice in the orchard, the idea being that it will increase nut production,; it has also been used extensively in the Hamden plantation in

the belief that it would bring the trees in flowering at an earlier stage. It will, however, do more damage than good, if it is not applied with care.

In Bulletin #2 from the Pennsylvania Chestnut Tree Blight Commission 1912, (7), we find the following statement: "It is believed that a healthy, rapidly growing tree is less liable to infection and will certainly recover better under treatment." To obtain this condition the application of fertilizer in the following amounts was recommended.

Per 100 sq. ft.

4 oz. muriate potash	(Potash-content 50%)
13 oz. nitrate soda	(Nitrogen-content 15%)
14 oz. acid phosphate	(Phosphorus-content 14%)

Per acre:

100 lbs. muriate potash (50%)

330 lbs. nitrate of soda (15%)

350 lbs. acid phosphate (14%)

More recently Diller & Whittaker & Anderson (37) have worked along the same line, and have tried to establish some facts with regard to the effect of fertilizer on the susceptibility to the blight. They treated 64-50 year old Japanese chestnuts with different amounts of N. P. and K. This experiment and results can be summarized as follows. The fertilizer was applied in March 1944 and 1945 and in the following combinations: 1. 300 lbs. N. annually. 2. 150 lbs. N. annually. 3. 300 lbs. N. once. 4. 300 lbs N. once & P-K in 1944. 5. 150 lbs. N. annually & P-K in 1944. 6. 300 lbs. N.

annually and P-K in 1944. 7. P-K in 1944. 8. 8 trees were not treated but used as a check.

The only treatment which had any effect on the growth rate was #3. 300 lbs. N. in 1944; it increased shoot growth significantly, but a second application (treatment #1) had no effect.

Inoculations with the blight were made in July, 1945. The results seem to indicate that an application of P-K a year before the inoculation increases the susceptibility to the canker; this effect was modified in a complicated manner by treatment with nitrogen. The experiment, however, was too small to give a conclusive explanation of the effects, and further studies are necessary and highly desirable.

The Bureau of Plant Industry (6) recommends the application of a 6-8-6* commercial fertilizer, using 1-2 lbs. for each year of tree age, that is a 4 year old tree can take 4-8 pounds of fertilizer. The fertilizer should be applied 2 weeks before the growth starts.

Graves mentions an application of 5-9-5 commercial fertilizer in his report from 1936, and states that the high amount of phosphorus was applied with a higher nut production in mind.

Too heavy an application and a careless job by which the tree trunk is covered with the fertilizer is very injurious to the trees. Cases have been experienced at the Litchfield

* Clapp (25) gives the following definition of grades of common fertilizers. "A grade is a name based upon the percentages of nitrogen, phosphoric acid and potash. Thus a "7-7-7" grade is the name of a grade which analyzes 7 percent nitrogen, 7 percent phosphoric acid and 7 percent potash."

plantation where this treatment killed trees of up to 1" in diameter outright. The fertilizer should be broadcast beneath the tree to a distance of about 1' beyond the spread of the crown (7) and about 1' from the base.

Fertilizer must not be applied at the time of planting (26 & 35) and not too late in the season, since it will then delay the ripening of the shoots.(26).

Graves has used manure extensively in his plantation at Hamden, and where it is possible to get it at a reasonable cost it should be used rather than the chemical fertilizer. At Hamden it is applied in the spring or the very early summer and placed on the ground just aroung the base of the trees.

INJURIOUS AGENCIES

I. Unfavorable Environmental Factors

Water relations:

The American chestnut is said to be fairly resistant to drought (96) unless the evaporation conditions are suddenly changed. Thus if a plant, which has been suppressed under a forest canopy is suddenly exposed to the full sunlight by removal of the overstory, it is apt to succumb. (96).

The Asiatic chestnuts are injured by drought, thus there were great losses in the dry years 1930 and 1931. (16, 92). They are especially susceptible to this type of damage in the earlier years of their life, when they only have a shallow root system. (92).

Very dry summers seem to give nuts of smaller size. (19).

The only practical way of prevention is to choose a site with a soil of a good waterholding capacity. Also planting under partial shade has been mentioned as favorable. (16).

The importance of the right level of the water-table has already been mentioned under the discussion of the site requirements. Here it may be emphasized that a high water-table gives weak slow growing trees, which easily will succumb to fungous diseases such as the chestnut blight and Phytophthora (mentioned below).

Exposure to extreme temperatures:

Three types of frost injury commonly occur, the early fall frost that nips the young shoot, which is not yet quite ripe; extremely low temperatures during the winter, which may

kill large parts of the cambium layer on older parts of the tree and sometimes kill the trees completely; and late spring frost which kills the young tender leaves and flower buds.

The injury in the fall is the least common according to Clapper & Gravatt (27). This statement, however, does not agree with most of the other authorities which mention all three types ofinjury with the same weight. (16,26, 31). It may be added, that the writer found several trees, including C. Henryi and C. margaretta, injured by a light night frost in late September, 1947.

A severe injury of this type took place in the south in November, 1940 as recorded by Crandall. (31). A summary of his article will be of interest, because it is a good example of the conditions, which render the trees especially susceptible to fall freezes. The weather in October until November 7th had been generally mild, and heavy rains in early November broke a period of severe drought. Apparently this kept the trees from reaching a dormant condition. Of the same effect was late season cultivation, mulching, releasing from competing growth and fall pruning. When then in mid-November, the temperature fell to 12°-14°F the losses were severe reaching as much as 100% in some places. C. mollissima and C. crenata suffered equally, while C. Henryi strangely enough was not hurt at all. The article strongly emphasizes how important it is that pruning, cleaning, cultivation, etc. is undertaken in the dormant season or early summer.

At the Hamden plantation no pruning, fertilization or cultivation is done after the first week in August, because of the possibility of a situation like the above.

With regard to extremely low temperatures in the winter, -25°F and below have been mentioned as fatal. (27). This agrees very well with Dr. Graves' records from 1934 and 1935 where he mentions -24°F as being fatal. Fluctuating temperatures between extremes in midwinter are, according to Clapper (27) exceedingly harmful. Blake & Edgerton (19) mention an interesting type of winter injury. They found that trees with large crotches just above the ground were especially susceptible to attack from the blight. They suggest that it may be associated with winter injury of such tissues, but do not, however, explain why the bark tissues in the crotches are more susceptible to winter injury, than the bark on the main stem. Is it possible that water accumulates in such places and when it freezes, expands and crushes the surrounding bark? This may also be explained on the assumption that the fungus is a facultative saprophyte, living first on the dead tissue and at length, invading the living bark.

Spring frost has been mentioned by several authors. (16, 26,31 91). Clapper & Gravatt 27 report that a freeze of 24°F on the nights of April 4 and 5, 1945 was enough to injure the trees visibly. The freeze was preceded by two weeks of abnormally warm weather.

How then do the various chestnut species rate with regard to susceptibility to the cold? The American chestnut is altogether hardy although one writer (109) says that it is "most sensitive" to frost. The Asiatic chestnuts, however, are all more or less injured. C. Henryi and C. seguinii both being killed back to the ground repeatedly. Of the Chinese and Japanese chestnuts the Japanese is the most susceptible according to Clapper & Gravatt. Graves (57) mentions a similar case. While the Japanese trees were severely injured, the Chinese trees remained healthy after a low of -24°F in the winter 1933-34. In the report for the next year (58) he however states that also the Chinese trees were severely injured in that winter.

The European or Spanish chestnut, C. sativa, is perhaps the least hardy of all species in Hamden. Of the American chinquapins, C. ozarkensis and C. pumila are the most hardy, while C. alnifolia and margaretta are severely injured. With regard to the hybrids it can be said that generally they will show a hardiness which closest resembles the hardiness of the dominant parent.

Control methods have already been mentioned. They can be summarized as follows:

1. Avoid frost-pockets, and choose the site with good air drainage.

2. Choose the right time for pruning, release-cuttings, cultivation, fertilization, etc. The dormant season, the earliest part of the summer, or, for pruning, the fall and

winter are good times.

3. Introduce the foreign species from the areas, which closest resemble with regard to climate, the areas to be planted in the United States.

Other Unfavorable Environmental Factors:

The chestnut when young, have a relatively thin bark, and so are injured severely by fire. Therefore, a good system of fire protection is essential if a plantation is to be successful. (35).

Reed (91,92) has reported damage from sunscald on the Chinese chestnut; especially when it is a young plant with thin bark. Also the other species must be expected to suffer from this source. When pruning and release cuttings are carried out this should be kept in mind, and the trunks not suddenly exposed to full sunlight.

Damage from sleet and ice storms has also been recorded by Reed.(91,92). He states that especially are the young Chinese chestnuts damaged, because they have a tendency to keep their leaves through the greater part of the winter. It can here be added that the twigs of C. mollissima are more brittle and easier to break than those of the other species. No means of control are known to the writer, but it is advisable to keep this in mind, when trees are selected for further breeding. Only the trees of sturdier growth should be favored.

II. Pathogenic fungi.

The Chestnut Blight Endothia parasitica (Marr) A & A

No attempt will here be made to describe the chestnut blight. The literature on the subject is large and easily accessible. A few problems which are of particular interest in the breeding work should, however, be mentioned.

Throughout this paper the term resistance to the blight has been used repeatedly but what is resistance to the blight, how can one tell a tree is resistant?

Only very little is known with regard to the reason for the differences in resistance among the various chestnut species, but the resulting effects on the trees can be plainly seen, and those will be described here.

No resistance as shown by young sprouts of most American chestnuts will be indicated by fast growth of the fungus beneath the smooth bark. The bark is not broken and is only raised very little if at all. The spreading mycelium can be seen as an orange discoloration through the thin bark. Even older sprouts will sometimes show a similar type of injury with the outerbark remaining unbroken but it usually takes such a long time for the fungus to kill the tree that the red fruiting bodies of the fungus can be seen in the canker before the tree succumbs.

Somewhat more resistance is shown where a canker develops. Two types are generally found, the swollen or hyporotrophic one and the sunken type with the raised edges. Both are definite signs of the host's fight against the para-

site.

On the least resistant trees the sunken cankers will be lined with an irregular edge of callus mixed with dead tissue. The newly formed callus is continuously attacked by the blight which keeps on extending the infected area. The most resistant trees will show a regular roll of callus around the canker, and here the picture is reversed; it is the callus which continually is closing in on fungus and eventually will overcome it. In the swollen type of canker it seems to be a fight in depth, the fungus tries to reach the cambium layer while the tree seems to cut off the advance by the formation of wound tissues. (91). Somewhat similar is a type of resistance which often is found on the Chinese chestnut, here the fungus only grows in the outer bark where it is checked and eventually succumbs, but no swollen canker is formed.

Will a resistant strain of the American chestnut eventually develop? The question has been raised repeatedly in the literature, (11,30,51,59,79,80). Aughanbaugh (11) mentions the following indications of the American chestnut's higher resistance in the years after the blight started; they are a good summary of the thoughts expressed in similar references, and are therefore given here. 1. Continuous sprouting from the stumps of the old diseased trees. 2. The sprouts grow to larger sizes now than formerly. 3. More sprouts come into bearing. 4.It takes longer for the blight to kill the trees. 5. Partially healed cankers are more common on the trees now. Ten years earlier, but with the same conditions in mind, Col-

lins (30) interpreted this as follows. Either (a) the disease is progressing more slowly or (b) the host is more successfully resisting the disease,or (c) the more susceptible trees have been killed, or (d) some other factors are influencing the results. The most important would be if the trees were developing more resistance, because this would simplify the breeding tremendously. That such a development actually is possible by mutation has been pointed out by Graves. (58). He is constantly on the look-out for this possibility, and plants all the native nuts he can obtain, to have them under observation. The relative susceptibility and resistance of the various species and hybrids has been summarized in Table #7, page

The "Ink-Disease", Phytophthora cinnamomi.

This "root-rotting"fungus is found from Maryland and south through the range of the chestnut, where it especially on the lower elevations has killed large numbers of chestnuts in the last hundred years. Gravatt & Fowler (47) state, that if all the American chestnuts which have been killed by this disease were gathered in a pure stand, they would cover 2¾ million acres (compared to 10 million for the chestnut blight).

Symptoms vary very much. Sometimes large trees are suddenly killed, starting with a severe wilting of the leaves in early summer followed by defoliation and death. More often, the slow loss of roots is indicated by an annual reduction in the size of leaves, accompanied by chlorosis and slight wilting. A few limbs die, and the leaves and burs are persistent

longer in the fall. In this case the trees usually die in the dormant season.

The lesions of the roots are often indicated by an inky-blue exudate, that stains the surrounding soil.

Causal fungus:

The tap root is first invaded, presumably through healthy bark; it has at least been found that wounding does not increase the number of successful inoculations.

The edge of the young invasion is mottled light brown and green advancing in wedge-shaped streaks; later a more definite margin is formed. The surface of the older lesions is brownish-black.

Isolation cultures are difficult to make. Oatmeal agar is the best culture medium. Here the fungus develops an aerial growth of hyphae and chlamydospores* are formed. On cornmeal agar only little aerial growth is formed, but many swollen hyphae tips can be seen. Sporangia and zoospores** are found only in running water.

Hosts and their susceptibility:

The following chestnut species are said to be attacked: Castanea dentata, C. sativa, C. pumila, C. ozarkensis and C. alabamensis. All four Asiatic chestnuts, C. mollissima, C. crenata, C. seguinii and C. Henryi are highly resistant, which makes one suspect that the disease has been introduced from Asia.

*Resting spores.
**Spores which can move by means of cilia, formed in sporangium.

Most susceptible are trees growing on poorly drained, low,heavy soil or soil with a high water-table. Under such conditions also the Asiatic chestnuts are severely injured.

Control: Here again the importance of the choice of the right site conditions must be emphasized.

Only one other control method has been mentioned and its effectiveness is very doubtful. It consists in the exposing and cleaning of the attacked roots. When they are dried out, copper carbonate is applied with a sticker. (32,47,48,86).

Twigblight:

Where the Asiatic chestnuts are growing on poor sites especially those with poor air drainage, severe attacks of twigblight have been found.

Cryptodiaporthe castanea produces cankers and die back on branches and main stems of C. mollissima, C. henryi and C. crenata. It is sometimes quite damaging in the nurseries and may occasionally cause the death of young trees in the plantation; more often it kills only individual branches and thus causes a deformation and decrease in growth of the trees. (41).

Bedwell (17) has described a similar injury coursed by species of the following genera:Phomopsis, Sphaeropsis, Diplodia, Cytospora, Diplodina, Macrophoma, Fusicoccum and Phoma.

The fungi are all weak parasites,which gain entrance through injuries caused by one of the following agencies: drought, low temperatures, mechanical agencies, browsing or gnawing by rodents. Once established they become parasitic.

The attack by Phomopsis is characterized by the black pycnidia, and concentric calluses.

The Japanese chestnut is mentioned as more susceptible than the Chinese, which undoubtedly is connected with the lesser hardiness of the species.

The only possible control measure against twig blight is the selection of the hardiest strains of trees, and to plant them in good condition on the best sites with good soil and air drainage..

The large leaf spot.

This disease is characterized by large, more or less circular spots on the leaves. The spots when up to 1" in diameter are pale in color and have concentric zones near the edges of varying gray, yellow and brown.(77). Graves (50) states that the older spots attain up to 2½" in diameter and finally may kill the leaves. The lower surface of the spots has a mouldy appearance due to the projecting mycelium. The spores are formed in dense masses in the acervuli which appear as dark spots.

Monochaetia Desmazierii is always found in the spots, but its parasitism has never been proven. (77).

The injury seems to be slight,if any. Graves (50) states that it causes a loss in increment, due to the reduced assimilation area. Hedgcock (77) says that it causes considerable injury to the foliage, but not until late in the season (beginning in August (50) when the growth has stopped.

The fungus, which also attacks numerous other hardwood trees is found from Indiana to New Jersey and southward to Arkansas and Florida.

Armillaria mellea has been recorded as an active parasite on chestnut and oaks. (83). The attacks were limited to dry sites, the upper slopes and flat tops of rather rough ridges near New Berlin, New York, and in North Carolina on ridges where the dominant species was Chestnut Oak.

The fungus is apparently a rather weak parasite, but where the trees are already deteriorating due to a poor dry site, the fungus gains entrance and helps in increasing the rate of destruction.

Armillaria mellea is an easily recognized fungus. When the bark is removed from the diseased trees, the dark strings "shoe-strings" of rhizomorphs are found in abundance, also the yellowish-brown pileate sporophores which are found in large numbers at the base of the attacked trees are characteristic.

Diseases of the nuts:

The nuts are very susceptible to molds, and great care is required in watering the nuts which have been placed in the greenhouse for germination. Too much watering will invariably cause the nuts to mold. Also the nuts in storage must be watched carefully and any nut that shows signs of molding removed immediately. Dr. Graves has tried treatments with a copper compound (Trade name Cuprocide-Copperoxide) against this type of injury, but without success, the young hypocotyl being

injured by the chemical.

Gravatt & Fowler (47) have recorded a Gloeosporium-like fungus on the nuts in the south. It is first noticed as a dark spot on the bur near the stylar opening, the nuts begin to decay near the style and small blackened spots can be seen on the seed coat before it starts to turn brown. Later the seed coat seemed to be covered with a greyish mold. Not only the immature nuts are damaged but great losses occur in stored nuts. Especially the Chinese chestnut seems to be susceptible.

III. Injuries caused by Animals

Deer: All the various species of chestnut suffer equally from browsing injury of deer. And there is only little hope that a plantation will succeed in a location with a high deer population, unless control measures are taken. Fencing is, of course, the best, but also wirenetting around the plants will do the job, the netting should be at least 4-5' high. Both methods are very expensive and would hardly be justified in an ordinary forest plantation. Protection is required until the trees are about 1" in d.b.h. and 10' high.(36).

Rabbit damage is especially severe in the nursery and in young plantations where grass and brush yield shelter for the animals. The animals show a tendency to browse the plantation in patches, which of course is more damaging than when scattered individual trees were injured. (16). There is also some indication that the American chestnut is preferred to the

Asiatic species.

Control: Dr. Graves has used the covering of the young seedlings in the nursery with fresh pine branches with good results. 2½' high wire netting has been used in the plantation.

Squirrels and mice. The nuts are sought to such an extent by squirrels and mice, that establishment of plantations by planting of the nuts is impracticable.

Various methods have been used to avoid this menace, but all are very complicated and time requiring. Here only the so-called "Tin-can method" used by Diller (36) will be described. He took a No. 2 can, removed one end and cut a cross in the other with a heavy-bladed knife. The open end of the can was forced into the ground over the planted nut so that the top was flush with the ground, the four corners of the cross in the top was turned slightly upwards. The can does not have to be removed as it disintegrates completely within two or three years. By this method 15.5% of the planted nuts developed into seedlings; the figure speaks for itself.

In the nurseries the beds must be lined with wire-screens in the bottom, and must be covered with close fitting screens.

In locations with many squirrels, it is necessary to collect the nuts every day at the time of harvesting; otherwise the squirrels will get them.

Besides taking the nuts, the mice also gnaw the roots, stems and branches of seedlings and young plants. Sometimes

the trees are completely girdled, and the wounds always furnish a good place for the blight to enter.

Some protection may be obtained from (4 wires to an inch) fine hardware cloth guards dug into the ground so they rest on the root crown and extend about 18" above the ground. They are, however not too effective, the mice might dig under or climb over the net and damage the trees. (9).

Baiting with Rodenticide dusted on cut-up apples is recommended in the orchards. The best time of baiting is in the middle of October on clear warm days; 3-4 baits should be placed in each runway. Care must be taken to place the bait out of the reach of other wildlife. (9).

Cleaning the base of the trees for a radius of about 3' of all litter and weeds which will furnish shelter for mice is especially of value in preventing late summer and early fall damage; it is not effective when the snow is on the ground. (9).

Woodchucks sometimes damage the bark on the stems when they sharpen their claws. The wounds themselves are of little importance, but they may yield a good place for entrance of the chestnut blight. The damage is effectively checked by wirenetting.

The Japanese Beetle: has caused much damage in the plantation in Hamden. A short description of its characteristics, like history and control will be given here.

The adult beetle is about 1/2" long, 1/4" wide, broadly oval, and shiny metallic green. The wing covers are coppery brown. Very characteristic are the 12 white patches along the edge of the wing covers on the abdomen, 2 near the tip and 5 on each side. (74.97).

The larva is a "white grub" with three pairs of legs, it is about an inch long when fully grown. (74,97).

The pupa is about 1/2" long and 1/4" wide and of a pale-cream to tan color.

The first emergence of the adults occur in Connecticut about June 20th, and they immediately start feeding. In the case of the chestnuts they are first attracted by the catkins, but soon go to the leaves. (19). Mating begins soon after the emergence and continues throughout the summer. During the summer at intervals of several days the female digs into the ground and lays 1-4 eggs, a total 40-60 eggs are produced during her life span of 4-5 weeks. For the egg laying the beetle prefers medium-moist loamy soil with closely cropped grass, as it is found in towns and the like.

The eggs hatch in ten days and the larva starts to feed on the roots of grass and weeds at once. The winter is spent in the third instar as a larva. When the warm weather starts early the following summer the feeding is resumed, and it continues until early June. After a prepupal stage of about 10 days it pupates. After 1-3 weeks as a pupa the adult emerges from the ground. The life cycle thus takes one year. (74 & 97).

The injury is easy to distinguish because only the green tissue is consumed and the veins left behind, so that the leaves are skeletonized. In orchards a great amount of damage isdone to the fruits. The grubs may when present in great abundance kill the grass.

Control: Following are the more recent types of control, which have been used. (a) Destruction of the larvae in the soil with lead arsenate or DDT. (b) Destruction of the larvae with the "milky-disease". (c) Spraying with lead arsenate. (d) Spraying with DDT. (e) Introduction of natural enemies.

The spraying with DDT is the method, which has been used at the Hamden plantation because it has the advantage that the menace from the chestnut weevil is also checked by the treatment.

DDT is commonly used in a concentration of 3-5 lbs. of 50% wettable DDT powder in 100 gallons of water, or 2 tablespoonsful to one gallon water. This concentration will protect the foliage for seven to ten days, and should therefore be repeated weekly from about June 20th and until the attack stops. (97).

Hadley (74) gives the following recipe for Lead arsenate spray:

	Quantity required to make -	
	10 gallons	100 gallons
Lead arsenate - -	10 ounces	6 pounds
Wheat flour - - -	6 ounces	4 pounds
Water - - - - - -	10 gallons	100 gallons

The first spraying should be undertaken as soon as the first beetles appear, a second application 2-3 weeks later will increase the effectiveness of the initial application. This should be sufficient to yield protection for the rest of the season. Lead arsenate is poisonous to man and should be used with care. It causes a discoloration of painted material and should not be used near buildings. (74).

The grubs can be destroyed by an application of Lead arsenate or DDT dust on the ground at the rate of 1 pound per 100 sq. ft. and 6 pounds per 1000 sq. ft. respectively. After the dusting, the area should be watered so that the chemicals can soak into the ground. (97).

It is now possible to buy the "milky-disease"* spore dust in the stores. It is common practice to apply this in spots spaced 5'x 5', using a level teaspoonful per spot. Early fall is the best time for application. (97).

The Chestnut Weevil, the larva of which feeds on the nuts, is the worst pest of the chestnut. Where abundant it may render a whole crop of nuts worthless, if control measures are not undertaken. All species of chestnuts are equally susceptible.

Under the name chestnut weevil, two species are included, the large chestnut weevil Curculio proboscideus and the lesser chestnut weevil Curculio auriger. The two species are very

* A bacterial disease caused by Bacillus popillae Dutky. (97).

similar in appearance. C. proboscideus is about 8-11 mm long, brown in color mottled with yellow or clay color on the back and pale yellow beneath. The beak is extremely long about 12-16 mm on the female and 6-8 mm on the male, they are straight near the base in both sexes. (22).

The lesser weevil is of a darker appearance and much smaller, about 7 mm long. The beak of the female is 8-10 mm long and that of the male 4-5 mm. In both sexes the beak is curved almost from the base.

The larvae of the two species are very much alike, the larva of C. auriger is smaller and somewhat pale in color. Also the pupae are almost identical except in size. (22).

The life cycles of the two weevils have been shown in the figure below. The main differences are that the cycle is one year for the larger and two years for the smaller beetle.

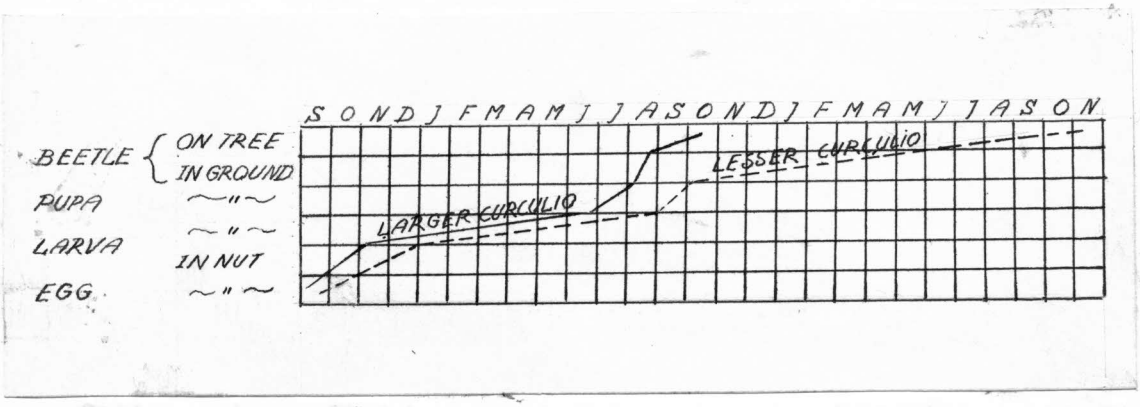

Figure 7. Seasonal cycles of the larger and lesser chestnut curculio. (After Brooks & Cotton).

The adults of C. auriger emerge already in the end of May or beginning of June, while the larger weevil is not seen on the trees until the middle of August. Oviposition takes place at about the same time.

The main type of injury is ofcourse the feeding of the larvae in the nuts, but it must be emphasized that even if the larval-activity is stopped at an early stage, the nuts will have lost most of their food value, because the meat takes a flat, musty flavor shortly after the eggs are laid. (22).

Nothing is stated about the injurious effect of the adults' feeding. They do, however, feed on the burs and catkins (on catkins of course only the lesser weevil).

Control: The weevil damage was apparently controlled last year at the Hamden plantation with DDT sprayed on the trees. The spraying must be timed right, so that it falls before the egglaying but when the beetles are present on the trees. (6).

Spraying with arsenical compounds has been tried but the results were far from satisfactory. (22).

Various treatments have been used to kill the larvae in the nuts. The so-called "hot water treatment" consists of immersing the nuts in a container with water held accurately at a temperature of 120°F for 30-45 minutes, depending on the size of the nuts. The temperature must not rise above 120°F, as higher temperature will injure the vitality of the nuts. Another treatment is fumigating with methyl bromide in tight

containers (1 ounce methyl bromide per 25 cu. ft.container) for 4 hours. Less satisfactory is fumigating with one ounce of carbon disulphide per 60 pounds of nuts for 15-16 hours. Both compounds must be handled with great care, as their vapors are poisonous, and carbon disulphide explosive when mixed with air. (5). The treatments will save the nuts for germination, but their food value has, as mentioned, already been destroyed, at least, as regards the infected nuts.

The Chestnut Louse, Calaphis castaneae a leaf-sucking aphid, has done much damage in the Hamden plantation.

The injury is characterized by numerous minute brown spots on the upper surfaces of the leaves. In years with severe attacks the entire leaf has a brownish color and will often curl up. The assimilation area of the trees are markedly reduced and the growth decreases.

The insect will be difficult to identify for anybody but the entomologist. The antennae are larger than the body and armed with short bristles. A few hairs are found on the head near the base of the antennae. The cornicles, the characteristic "spurs" on the abdomen of aphids, are short, somewhat tapering, broadened at the base. The wings are of a somewhat smoky color and more or less bordered with black. (13.21, 43).

The attack usually sets in about the middle of July and the spraying should start immediately afterwards, and continue

through the summer until the end of August with intervals of 2-3 weeks. At Hamden a mixture of soap and nicotine sulphate has been used successfully and if the first spraying is followed quickly by a second one or two days later the work is much more effective. (56,57,58,59). As to the effect of a DDT spray no information has been found, but it seems reasonable to assume that it would be effective.

The Two-Lined Chestnut Borer -Agrilus bilineatus is found in the Hamden plantation but the attacks are not very serious. One phase of the injury may, however, be of interest. Anderson (1) has mentioned the wounds caused by this beetle as possible entrances for the chestnut blight; they may also be of some importance in the spread of the blight both from one tree to another and on the individual trees.

The beetle is slender, black with a slight greenish tinge; some yellow pubescence is found on the thorax (breast) and in two lines and along the edges of the wing covers. The young grubs bore in the outer bark of the trees, but work deeper as they grow older, as full grown they are about 1/2" long, creamy-white with a peculiar pair of brownish anal forks and a fairly wide head. Pupa is white, and all appendixes are plainly seen.

Some aspects of the injury have already been described. For completeness it is however necessary to mention that the main type of damage is the girdling of the trees by the feeding activities of the larva. Such injury is not found in

Hamden. (24,88).

Control measures are few and not of much value. In Europe the use of trap trees is a common practice. Various repellants, painted over the trunk and larger branches have been used. Of such repellants, fish-oil and a mixture of lime, paris green and glue, can be mentioned. The treatment should be undertaken about the first of May. (24,88).

Spring and Fall Canker Worms, Paleacrita vernata and Alsophila pometaria, respectively

Both these moths are present in the Hamden plantation, and severe damage has been recorded once (59), in this case caused by the spring canker worm.

The caterpillars, or as they commonly are called "measuring worms" due to their peculiar manner of progression, are leaf eaters, and may when present in great abundance completely defoliate the trees.

The larvae of the two species are very much alike, quite variable in color, pale green, dark grey, brown or nearly black. They differ in their number of prolegs, the fall canker worm having 3 pairs, the other only 2. Of the adults, especially the wingless female is characteristic when she crawls up the trees to lay her eggs; this happens in the case of the fall species in the fall and early winter while the spring species deposits the eggs in the spring or early summer. (14).

For control, spraying with arsenate of lead has been

recommended..(14, 89).

Baldwin (14) gives the two following recipes.

Lead Arsenate	3 pounds
Water	100 gallons
Fish oil or linseed oil	12 ounces

or,

Lead Arsenate	100 pounds
Fish oil	10 gallons
Paraffin oil	1½ gallons
Water	70 gallons

The latter mixture was used in the forest.

The spraying started at Hamden in the beginning of May and continued to the middle of June.

Banding of the tree trunks with some sticky substance which prevented the females from reaching the branches and lay their eggs, is also commonly used.

The "Seventeenyear Locust" Magicicada (Tibicen) septendecim (L) has appeared in the plantation, and caused a rather severe deformation of some trees. No measures are known to prevent the larvae from feeding on the roots (for seventeen years) and it will be several years before the females reappear and do this destructive job of egg laying.(38).

SUMMARY

The chestnut breeding work was started in 1930 by Dr. A. H. Graves, and by the Division, Forest Pathology, United States Department of Agriculture about 1928, the main object being the development of a new timber type of blight resistant chestnut hybrid.

The self-sterility of chestnut is a result of duo-dichogamy and self-incompatibility.

A complete botanical description has been given of the following chestnut species and hybrids: C. dentata, C. crenata, C. mollissima, C. seguinii, C. Henryi, C. sativa, C. pumila, C. ozarkensis, C. ashei, C. alnifolia, C. margaretta, C. crenata x C. dentata, C. mollissima x C. dentata, C. mollissima x seguinii, C. crenata x (C. crenata x C. dentata), (C. crenata x C. dentata) x C. dentata, C. dentata x S.8, and C. mollissima x (C. crenata x C. dentata).

The greater part of the description is based on herbarium material collected in the Hamden, Conn. plantation inOctober, 1947.

The van Fleet hybrid S-8, which commonly has been called C. crenata x C. pumila is according to the available information probably the reciprocal cross C. pumila x C. crenata.

The most promising hybrid yet developed is C. mollissima x (C. crenata x C. dentata); it shows definite hybrid vigor and a high degree of resistance. Only a few specimens are, however, of good form.

In table #7 the growth rate, dominance, form of growth, and blight resistance of some 350 trees in the plantation has been summarized.

Asiatic and hybrid chestnuts require a dry, well-drained fertile soil of good water-holding capacity. Good drainage and plenty of light is essential.

The best way to develop seedlings, is immediate planting of cured nuts in pots in a cold frame, and covering in the coldest winter months with leaves. Rodent protection is essential. Proper planting is essential; best planting stock is 1/1 or 1/2 transplants.

Weeding and release cuttings are essential in early part of life, as the chestnuts cannot compete with other growth.

The application of commercial fertilizer requires great care. Grades 6-8-6 and 5-9-5 have been recommended.

Of the Chinese and Japanese chestnuts the Chinese is the most hardy.

A good fire protection is essential.

Damage from sunscald and ice is not uncommon, the Chinese species being the most susceptible to the latter type of injury.

The following fungi and animal enemies have been mentioned briefly and their possible control discussed: Endothia parasitica, Phytophthora cinnamoni, twig blight, Cryptodiaporthe, Monochaetia Desmazierii, Armillaria mellea, molds on nuts, deer, rabbits, squirrels, mice, woodchucks, Japanese beetles, chestnut weevils, Calaphis castaneae, two-lined chestnut borers, canker worms and the "seventeen-year locust."

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I

APPENDIX

An Attempt to Hasten the Germination of the Chestnut

Before the experiment itself is described and the results discussed, it may be of interest to mention briefly the factors which may influence the delay of the germination of seeds; and former experiments with similar objectives as the present work.

The dormancy of seedsor the inability of seeds to germinate under conditions favorable for germination may be due to the following causes: (1) a rudimentary embryo which must mature before germination can take place; (2) an impermeable seed coat which inhibits the absorption of water, and possibly of gasses; (3) coat structures which offer mechanical resistance to the expanding embryo and seed contents; (4) incasing structures which limit oxygen absorption by the embryo and possibly the elimination of carbon dioxide from it, resulting in the limitation of processes dependent upon them; (5) a state of dormancy in the embryo itself or in some organ of it, in consequence of which it is unable to grow when naked and supplied with all ordinary germinative conditions; (6) combinations of two or more of these; and (7) assumption of secondary dormancy. (3,5,17).

In the past the attempts to hasten germination of seeds have followed the following lines:

1. Temperature pretreatment:
    a. Relative high temperature 32-34^{0}C (4).
    b. Temperatures between 1^{0}-10^{0}C (1,3,10).
    c. Temperatures below 0^{0}C. (10,17).

2. Pretreatment with various chemicals.
   a. Treatment with inorganic compounds.(10).
   b. Treatment with organic compounds. (6,7,10).
   c. Treatment with various vapors and gasses. (6,7,9).
3. Pretreatment with various enzymes. (12).
4. Various pretreatments used to overcome impermeability or mechanical effect of seedcoat.
   a. Mechanical abrasion of the seeds. (3).
   b. Corroding the seedcoat with various acids and bases. (16).
   c. Soaking in hot water. (18).
   d. Pretreatment with various wax solvents. (14).
5. X-ray treatments, and treatment with ultra-violet rays. (2,10).
6. Treatment with electro-magnetic waves. (10).
7. Treatment with high pressure. (10).

In the present experiment treatment with various temperatures, with gasess and with wax solvent is mainly of interest, these being the ones tried. Therefore, some of the earlier experiments along these lines will be discussed somewhat more in detail.

Baldwin (1) found in the case of White Pine, Pinus strobus, that a treatment with 8°-10°C over a period of 4 weeks gave an increased rate of germination.

Treatment with 1°C, and alternating temperatures from 1°C to 5°C, alternated daily or weekly, were found by Flemion (10) to be the best condition for the afterripening of seeds of Sorbus aucuparia, which have a dormant embryo.

Temperatures below freezing have been used by various workers. Jacobs (12), working with Sugar Pine, Pinus lambertiana, hastened the germination with a pretreatment of the seeds of -12°C for 48 hours. The moistened seeds were placed between 3 cm thick layers of sand, and were thawed gradually over a period of 24 hours. Flemion (10) got no germination of S. aucuparia seeds for one, two and three months at -8°C. Much lower temperatures (-80°C, -180° to -190° and -269°,2C) have been used by some workers; in a few instances with good results. (17).

Of experiments, where various gases and vapors were used, especially the work by Deuber (9) is of interest, because he worked with Black Oak (Quercus velutina) acorns, which perhaps could be expected to act somewhat like chestnuts, the two species being rather closely related. Deuber treated the acorns with mixtures consisting of various percentages of air and "mixed" gas for 24 hours, and found that the germination was greatly increased, the best mixture being 50% "mixed" gas and 50% air; a 1.25% mixture of ethelane in air was also found to be effective.

The seeds of legumes are well known for their impermeable seed coat and several workers have tried different treatments which would overcome this. McKeever (14) found in the case of Black Locust, that the impermeability was due to a wax layer in

the seed coat. He treated the seeds with wax solvents such as acetone, xylene, ether, benzene, etc. for 10, 30, 60 and 120 minutes and found that the germination was materially increased; in some instances up to 41% germination was obtained in five days after treatment.

Material for the present Study

The greater part of the material was Chinese and Japanese chestnuts collected in the plantation in Hamden. The material was divided into ten lots of 100 nuts* for each species. Lots No. 1-5 had been cured at room temperature in open paper bags for some days. On October 16, after 96 hours exposure to 40°-44°F in a cold storage they were mixed with slightly moist "Mica Grow" and placed in sealed fruit jars under the final pretreatment conditions. These will be described later. Lots #6-10 were also cured for several days at room temperature. Thereafter, October 23rd, after 24 hours exposure to 40°-44°F they were placed under the final conditions in a similar manner as Lots # 1-5.

Some 200 European chestnuts were bought on the market in New Haven, and planted directly in the greenhouse. The nuts were said to be of Italian origin, and had been as far as could be determined shipped to this country in charcoal dust.

A few American nuts were received, and planted directly in the greenhouse.

*Lot #2 and 5 of C. mollissima were only 80 and 50 respectively. Lot #7 were of 80 nuts for both species, #8 C. crenata and #8 C. mollissima, 80 and 50 nuts respectively, # 9 and 10 only involved C. crenata.

V

METHOD

I. Temperature treatments:

Lot #1 (both species) was placed in room temperature, and a sample of 20 nuts was taken out at two week intervals and planted in flats at 50°F.

Lot #2 (both species) was placed in 40°F, and samples of 20 nuts taken out at 2 week intervals and planted as #1.

Lot #3 (both species) was treated with alternating temperatures of 36°F and 40°F as follows:

Sample a. 2 weeks at 36°F and 2 weeks 40°F.

Sample b. 2 weeks at 36°F, 2 weeks at 40°F and 2 weeks at 36°F.

Sample c. The same treatment as sample 3 B followed by 1 week at 40°F and one week at 36°F.

Lot #4 (both species) was placed in 48°F, and samples of 20 nuts taken out at 2 week intervals and planted as #1.

Lot #5 (C. crenata) was placed in 40°F, and samples of 20 nuts taken out at 2 week intervals and planted in the greenhouse in flats.

Lot #6 (both species) was placed in 36°F and samples of 20 nuts taken out at 2 weeks intervals and planted as #1.

Lot #9 (C. crenata). After 2 weeks at 36°F a check sample of 20 nuts was taken out and planted at 50°F as lot #1. The rest of the lot was placed between 1" thick layers of sand in a cardboard box and exposed to about 8°F for the following length of time: (1) sample (b) 24 hours; (2) sample (c) 48 hours; and (3) sample (d) 96 hours.

Lot #10 (C. crenata) was placed at 36°F and samples of 20 nuts taken out at 2 weeks intervals and planted in the greenhouse in flats.

II. Treatment with a mixture of "mixed" gas and air.

Lot #7 (both species). After 2 weeks at 36°F a check sample of 20 nuts was taken out and planted at 50°F in flats. The rest of the lot was treated with 25% mixture of "mixed" gas and air for the following length of time: (1) sample #b, 7 hours; (2) sample #c, 24 hours; and (3) sample #d, 96 hours.

The procedure with the "mixed" illuminating gas supplied to the laboratory outlets by the New Haven Gas Light Company, was to fill a large Erlenmeyer flask 1/4 full of water, invert the flask under water and displace the water with the "mixed" gas. The next step was to force this mixture into the liter Erlenmeyer flasks containing water and 20 nuts and inverted under water. The flasks containing the nuts were then stoppered under water and placed at out-of-doors temperatures for the above mentioned time, and next the lots were planted at 50°F.

III. Treatment with wax solvents.

Lot #8 (both species). After 2½ weeks at 36°F a check sample of 20 nuts was taken out and planted at 50°F in flats. The remaining part of the lot was divided into 3 samples of 20 nuts, and treated with acetone, xylene or ether*

* In the case of C. mollissima the treatment involved only xylene and ether.

for 30 minutes; after the treatment the samples were allowed to dry and were planted the following day at 50°F in flats.

Lot #5 (C. mollissima). After 4 weeks storage at 40°F, 20 nuts were taken out and planted in flats at 50°F as a check sample. The rest of the lot was treated with Acetone for 30 minutes, and finally, the next day planted at 50°F.

After the treatment a sample of 50 cc. was taken from the solvents, evaporated and the residue weighed.

In all cases where the nuts were stored over a longer period of time in the sealed fruit jars, the jars were removed from the storeroom twice a week and placed in fresh air with the lid removed, to renew the air in the jars.

With regard to the choice of germination conditions, the decision was difficult to make because none of the two possibilities was considered very favorable. One was a greenhouse where the daily temperatures fluctuated between 70°F at midday and 58°F during the night. These temperatures are rather high; Galloway (11) states that they should not exceed 40°F during the night and Korstian (13) found that temperatures fluctuating between 50°F and 65°F gave the best result with several of the oaks. Moreover, the chestnuts are very often injured by molding and it was feared, that damage from this source would be more severe on the higher temperatures. For this reason the 50°F was finally chosen in spite of the fact that a somewhat fluctuating temperature is the best in most cases. (3,13).

The final count of germinated nuts was made February 2, 1948 for the entire experiment (with the exception of C. sativa), and the germination percentage computed as of this date.

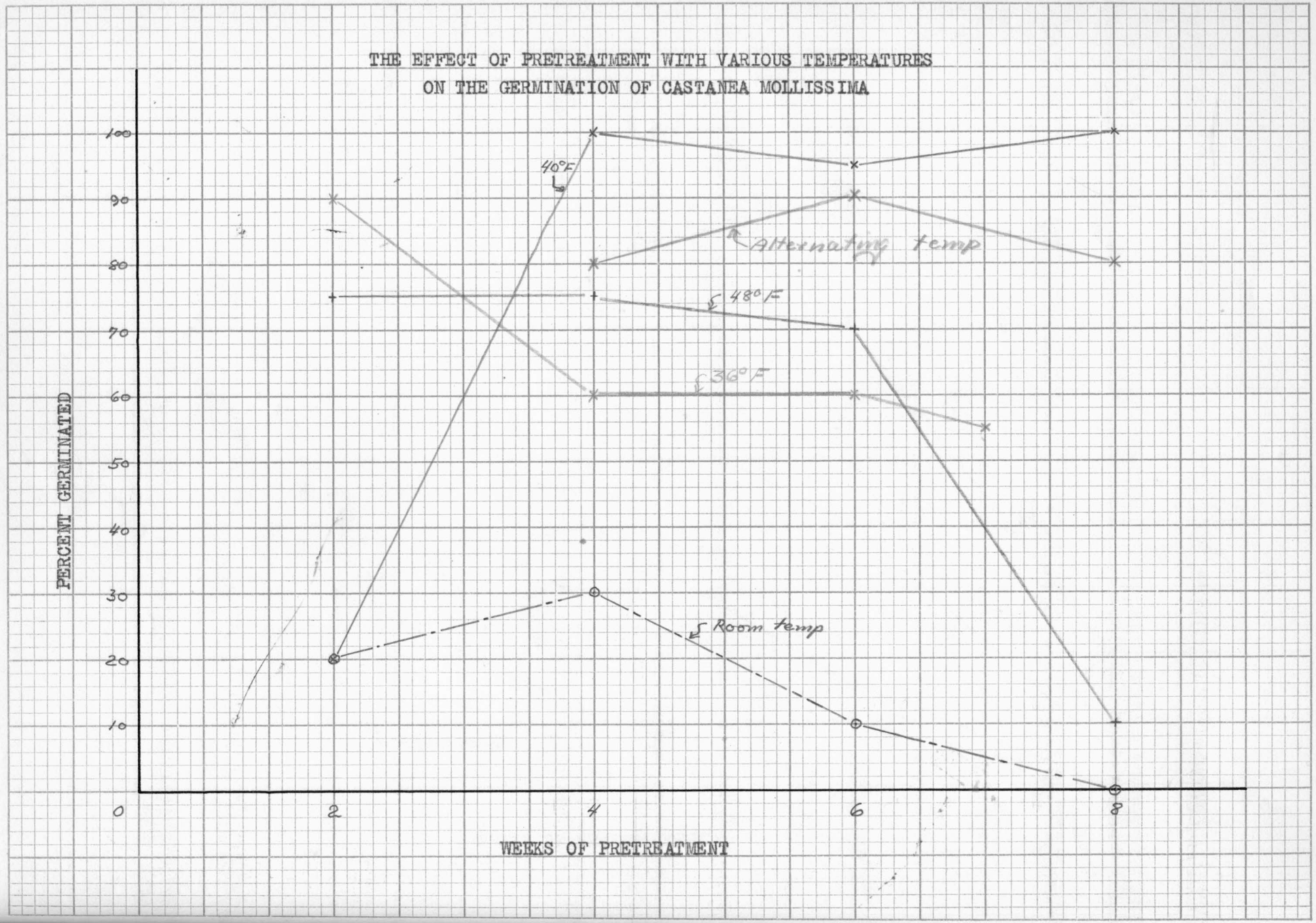
The nuts were considered as germinated when the radicle was protruding beyond the seedcoat; in other words the commonly accepted botanical use of the term germination was used. (3).

Results:

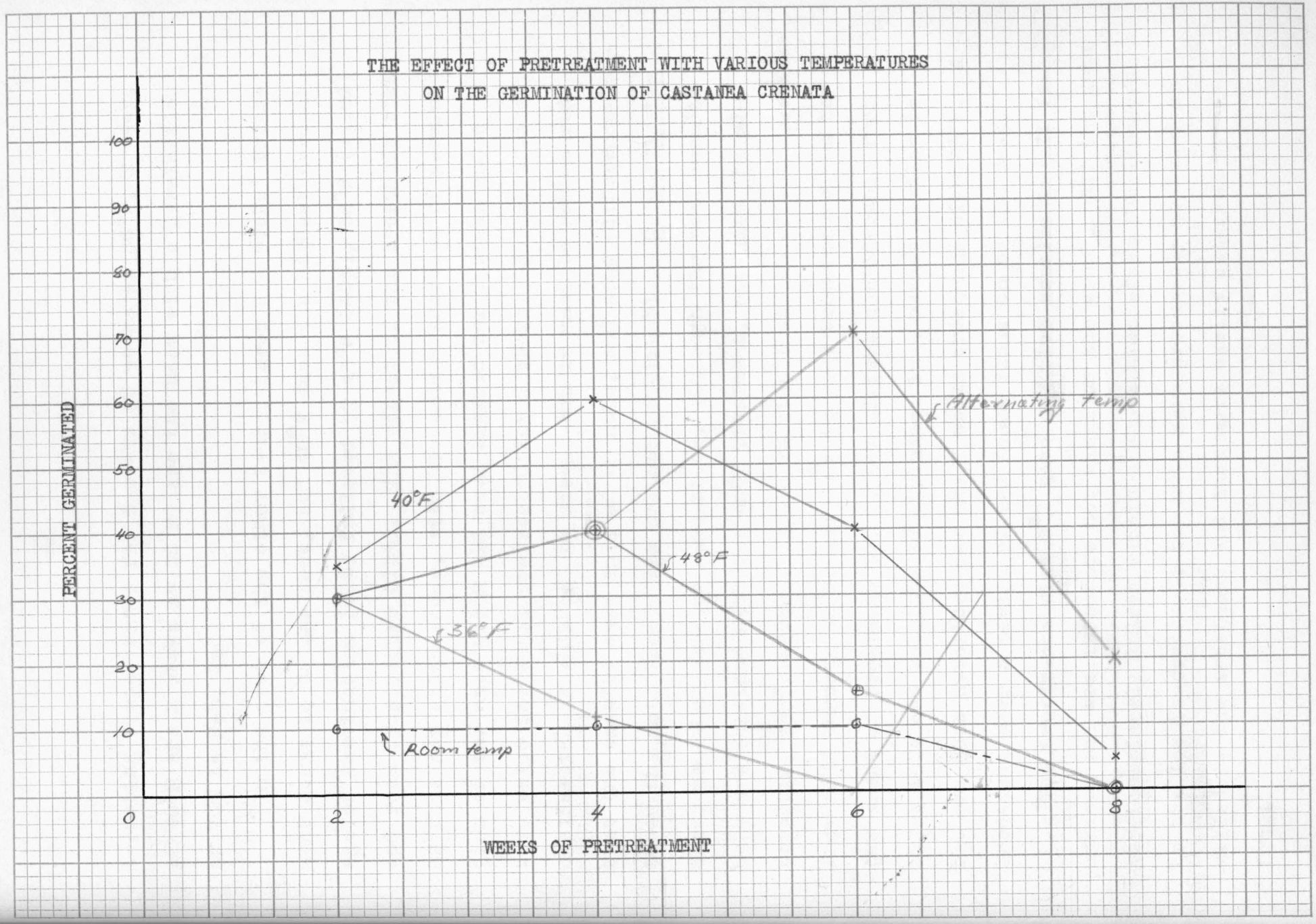
The four species vary considerably in their rate of germination. Fastest is undoubtedly theEuropean chestnut, although it is impossible to draw any exact conclusion, because the conditions to which they might have been exposed are unknown. The species did, however, germinate with 63.4% in six weeks which is faster than any of the other species. Next comes C. mollissima as can be seen when the graphs page VIIIa and page VIIIb are compared. The Japanese chestnut shows the lowest rate of germination. Only 26 American chestnuts were planted which gave any results (two other lots were destroyed completely by molding). They had germinated after about nine weeks, with 26.9%, but it is hardly possible to compare a small sample like this with the others.

The effects of the various temperature treatments have been shown on the graphs page VIIIa and page VIIIb Most clearcut are the effects in the case of C. crenata. Al-

VIIIa


THE EFFECT OF PRETREATMENT WITH VARIOUS TEMPERATURES
ON THE GERMINATION OF CASTANEA MOLLISSIMA
PERCENT GERMINATED
100
90
80
70
60
50
40
30
20
10
0
2
4
6
8
WEEKS OF PRETREATMENT
40°F
Alternating temp
48°F
36°F
Room temp

VIIIb


THE EFFECT OF PRETREATMENT WITH VARIOUS TEMPERATURES
ON THE GERMINATION OF CASTANEA CRENATA
PERCENT GERMINATED
100
90
80
70
60
50
40
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20
10
0
2
4
6
8
WEEKS OF PRETREATMENT
40°F
48°F
36°F
Alternating Temp
Room temp

ternating temperatures for 6 weeks (2 weeks at 36°F, 2 weeks at 40°F and 2 weeks at 36°F) are the best with a germination of 70% on Feb. 2nd.

In the case of the other temperatures a 4 weeks' treatment seems to be the best, and 40°F gave the highest percentage of germination (60%) followed by 48°F (40%), 36°F (11.8%) and room temperature (10%). The effect of the treatment with 36°F is not quite clear, with the sudden increase of germination of the nuts which had been treated for 7 weeks and a zero value for those pretreated for 6 weeks. No satisfactory explanation of this can be given, but it must be remembered that the samples were only of 20 nuts, and some differences between the nuts themselves are not unthinkable. C. mollissima shows somewhat similar conditions, although the best results here are obtained with the 40°F treatment, not with the alternating temperatures. Again we find that the effect decreases from 40°F through 48°F, and 36°F to room temperature. After two weeks of treatment the effect differs considerably from this; this can possibly be explained in a manner similar to the one just described for the 7 weeks treatment with 36°F. A treatment over a period of 4-6 weeks seems to be the best.

The treatments with 8°F gave negative results in all instances and are therefore not shown on the graph. All the nuts were completely molded within a short time after the exposure to the low temperature; the nuts were presumably weakened or killed by the treatment and thus more easily attacked by the fungi.

The effect of the gas treatment is shown in the table below.

Length of Treatment	C. crenata % germinated	C. crenata % still good	C. crenata % molded	C. mollissima % germinated	C. mollissima % still good	C. mollissima % molded
Check	35	15	50	90	10	--
7 hours	15	35	50	100	--	--
24 hours	11.8	47.-	41.2	50	50	--
96 hours	10	25	65	75	25	

Table #I. Effect of treatment with a 25% mixture of "mixed" gas and air, on the germination of C. crenata and C. mollissima.

It seems reasonable to conclude that the treatment was without favorable effect and that exposure over longer periods of time (24 and 96 hours) is damaging to both species, or at least induces a secondary dormancy.

Treatment	C. crenata % germinated	C. crenata % still good	C. crenata % molded	C. mollissima % germinated	C. mollissima % still good	C. mollissima % molded
Check	25	15	60	x95	5	
Ether 30mm	20	20	60	x30	40	30
Acetone "	15	10	75	*70	30	
Xylene "	10	20	70	x40		60
" 15mm				*30	50	20
Check				*85	15	

Table #II. Effect of the treatment with the wax solvents ether, acetone and xylene, on the germination of C. crenata and C.mollissima.

x Lot #8.
* Lot #5

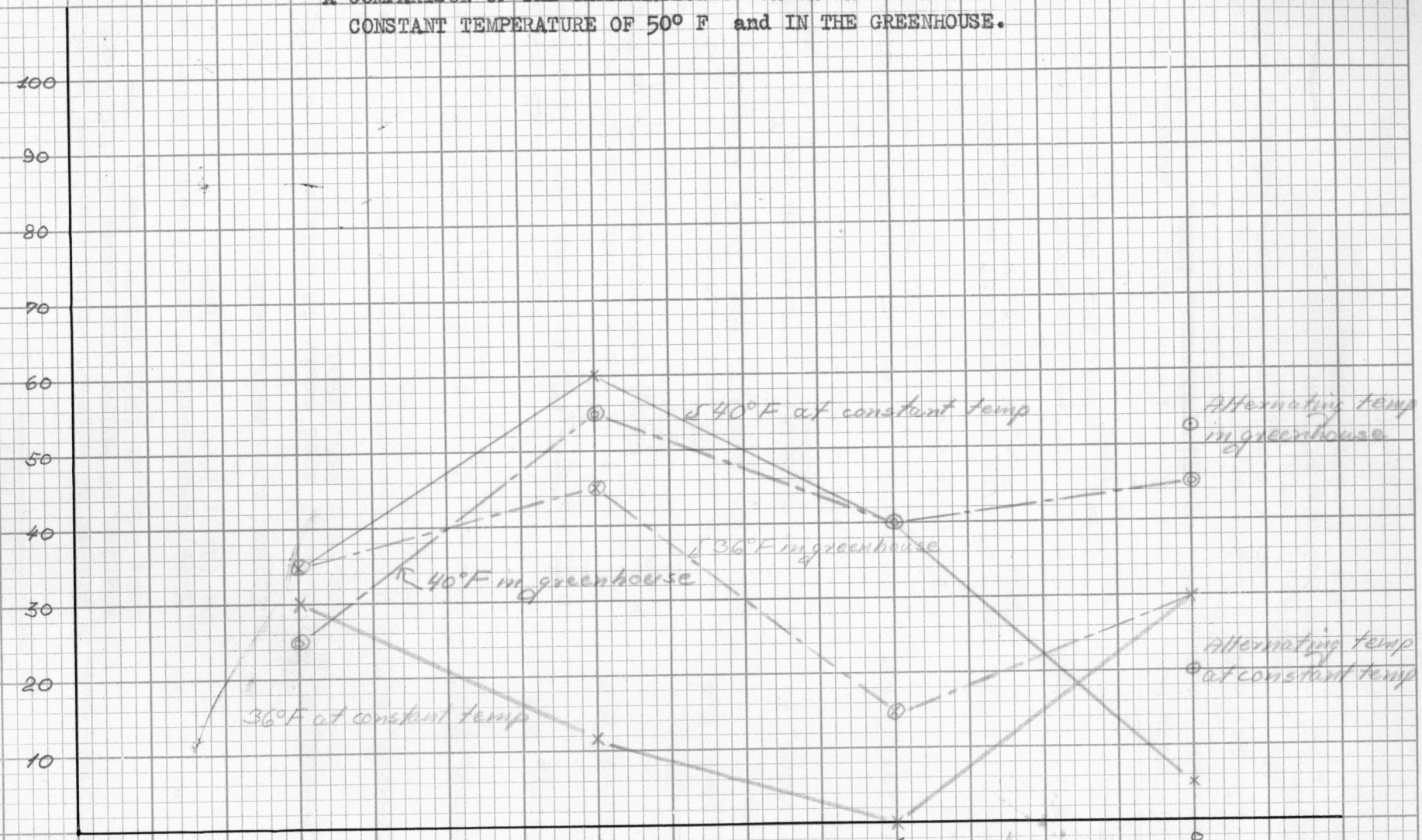
This type of treatment also seems to be more damaging than favorable and especially so in the case of acetone and xylene. The weighing of the residues indicated that the seedcoats of the nuts are without wax content, the residues being less than a few hundredth of a gram in all cases. This slight amount was probably due to the impurities in the solvents and did not come from the nuts.

Two series of samples were run for the 40°F and 36°F treatment with C. crenata; one was planted at the constant temperature of 50°F like the rest of the samples; the other was planted in the greenhouse. On the graph, page XIa the comparison is drawn. For the 36°F treatment it is obvious that the best results were obtained in the greenhouse, but for the 40°F treatment the results are reversed; it is thus difficult definitely to determine. which of the two conditions are the better for germination. There did not seem to be any difference in the amount of molding which occurred under the two conditions.

Conclusion

This experiment, which involved only 20 nuts for each type of treatment, cannot be considered as final in its results. It does, however, indicate that temperature treatments can give good results, and that if further experiments are desired, then there should be temperatures around 40°F and treatments over a period of 2-6 weeks, which should be tried out first of all.

A COMPARISON OF THE GERMINATION OF CASTANEA CRENATA AT A CONSTANT TEMPERATURE OF 50° F and IN THE GREENHOUSE.



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apex, base acute to rounded, mostly asymmetrical. Serration very fine, finer than on the form just described, 12-16 pairs of veins; veins glabrous on the upper surface and only sparingly hairy below.

Buds were not found, because they had developed into flowers on all the plants.

Flowers. As far as known the plants were used for cross pollination for the first time in 1934, but were blooming and bearing nuts before that time (55), any exact data are not available. Blooming starts in late June and continues to early October. Male catkins about 2" long.

Burs with long fairly rigid spines with short hairs. Spherical and with a diameter of 3/4-1". Spines turning brown as fruits ripen. Found all along present year's growth, solitary or two together.

Nuts usually three together in the bur. Brown with darker stripes. With short white hairs towards the apex,.4-.5" wide, .5-.6"high. Flavor good.

Thus, there are significant differences in these two forms. We are undoubtedly dealing with two varieties of the species, or perhaps with 2 species.

The Chinese Timber Chinquapin Castanea Henryi (Skan) Rehd Wilson

Castanea Henryi has a distribution in China which resembles very much that of Castanea seguinii. It is,however, found further south in eastern China than that species, occuring, ac-