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PROPAGATION OF A RAPID GROWING SEMI-EVERGREEN HYBRID OAK

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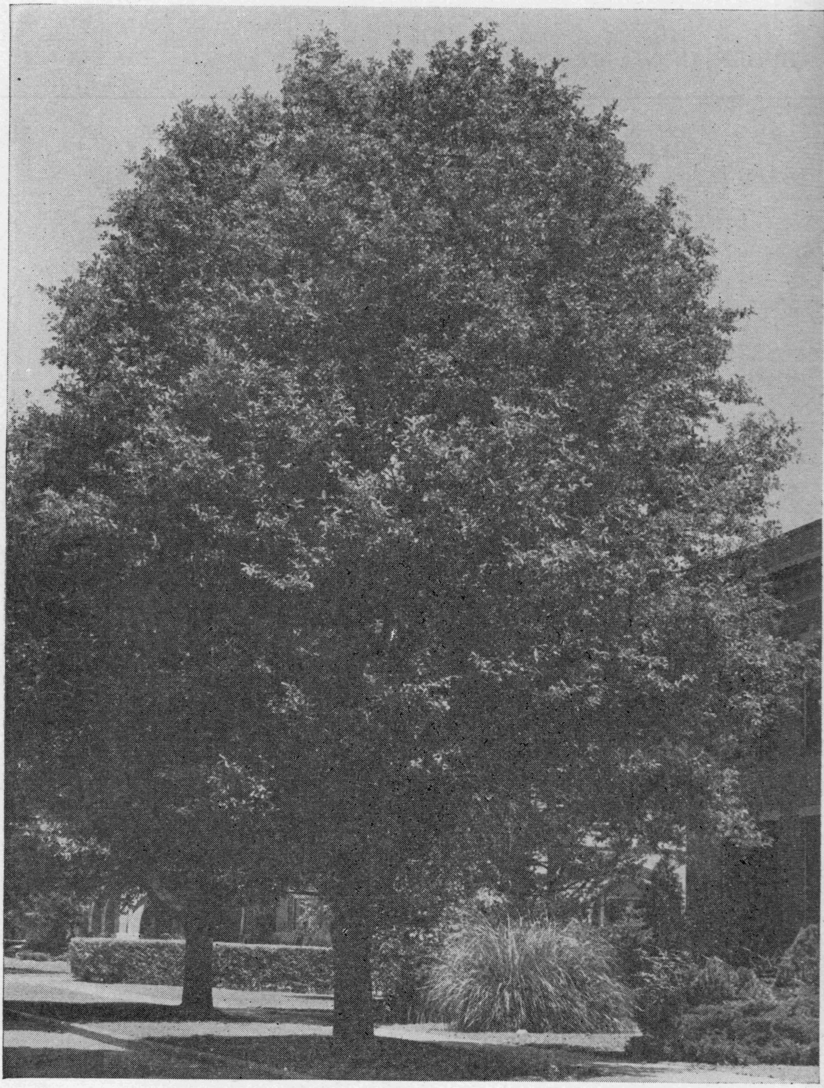

Figure 1. Frontispiece. First generation Ness Hybrid oaks. Approximately 30 years old. These resulted from pollinating the live oak with pollen of the overcup oak. Note the rounded, symmetrical, yet upright form, and the dense foliage.

A beautiful oak has resulted from a cross of the live oak and overcup oak made over 30 years ago by Helge Ness at the Texas Agricultural Experiment Station. It is a partially evergreen, round-topped tree that grows faster than either parent and should be well adapted for ornamental planting in east, central, and probably other parts of Texas.

Several successful methods are presented for the propagation of this desirable oak. It is shown especially that when scions are either whip or bark grafted on burr, live, overcup, post, swamp white and other stocks of the "white oak" group, a high percentage of good unions are secured.

Results have shown also that certain methods are unsatisfactory, and that one group of stocks have made poor unions; both should probably be avoided in nursery practice.

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PROPAGATION OF A RAPID GROWING SEMI-EVERGREEN HYBRID OAK

By

W. S. Flory, Jr.,[1] and F. R. Brison[2]

In 1909 Helge Ness[3], at that time Horticulturist with the Texas Experiment Station, pollinated some pistillate flowers of a live oak with pollen from an overcup oak. Three hybrids resulted. Similar crossses in 1910 gave 3 more hybrids. Additional crosses in later years gave still others. In securing these crosses[4] Ness was pioneering in a virgin field. So far as available published reports show, he was the first man in America and among the first in the world to produce artificial hybrids between species of forest trees.

The Texas Experiment Station has attempted to stimulate an initial interest in these desirable trees for ornamental purposes, and to develop suitable methods for their propagation. While the Station cannot propagate the trees for general distribution, and must rely on Texas nurseries for this function, it will gladly furnish lists of nurseries known to have Ness Hybrid trees as they become available. No attempt has as yet been made by this station to develop practical means of producing hybrids of hardwood trees on a scale necessary for commercial timber production.

THE MATERIAL

These hybrid oaks were first described by Ness in 1918 (10). In 1927 he published (11) further descriptive notes on the first generation hybrids and also briefly described the different classes of segregates in a second generation population. Segregation of characters in F_2, from a factorial standpoint, was later studied by Yarnell (17). Both Ness and Yarnell have pointed out that the first generation hybrids have a considerably more rapid growth rate than either of the parent species. This exhibition of hybrid vigor is striking when the original hybrids are compared in size with live and overcup oaks planted within a few years of the same time.

The first generation live oak × overcup oak hybrids are uniform. Their upright and straight-branched habit, inherited from the overcup parent is combined with a round top and in addition a greater regularity of outside contour than is usual for live oaks. The resulting upright-symmetrical form, so regular in outline as to appear sheared (Fig. 1), gives the hybrids a distinctive beauty. The lyrate leaves are inter-

[1]Horticulturist, Agricultural Experiment Station.
[2]Professor of Horticulture, School of Agriculture, A. and M. College of Texas.
[3]Deceased December 30, 1928.
[4]Ness also produced some hybrids, of less ornamental promise, between other oak species (see reference 11). Where the terms "Ness Hybrids" or merely "hybrids" are used in this paper, however, they refer to plants resulting from the live oak × overcup oak cross.

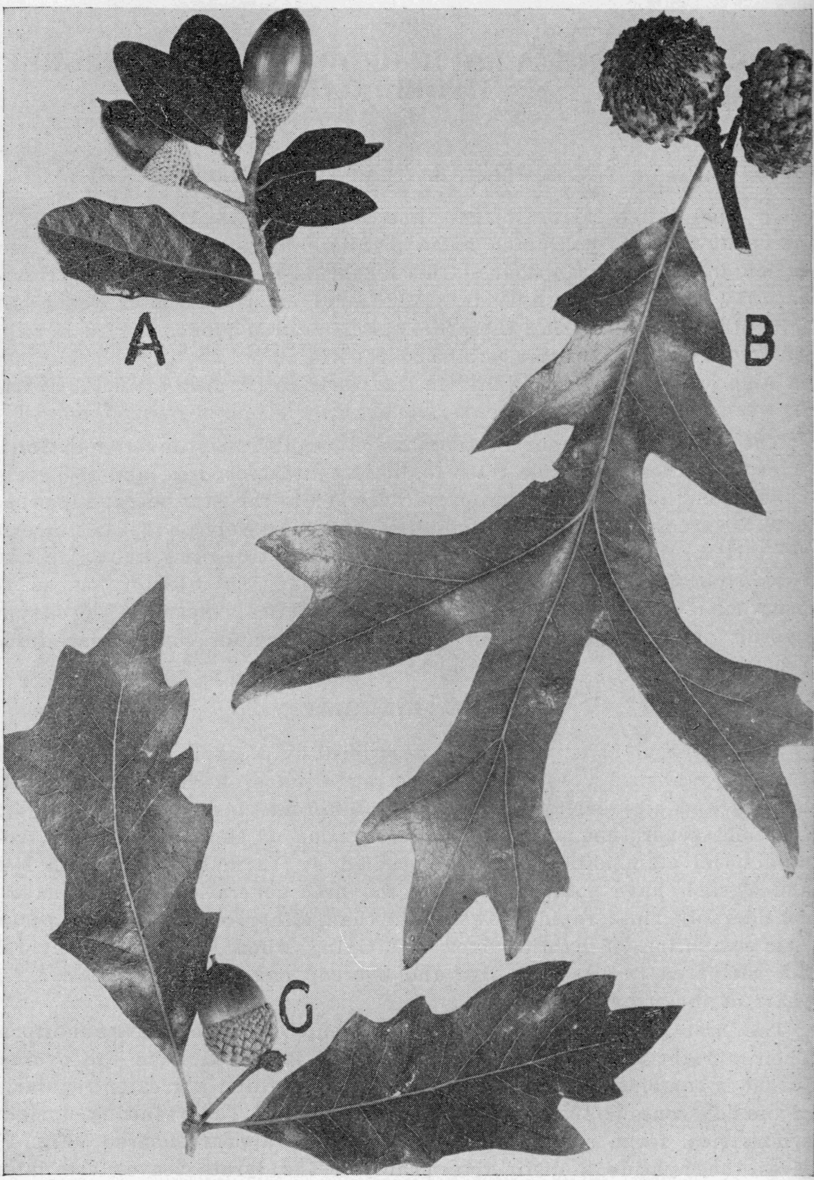

Figure 2. **Leaves and fruit of the Ness Hybrid oak and its parents. A.—the live oak parent** *(Quercus virginiana)*; **B.—the overcup oak parent** *(Q. lyrata)*; **and C.—the** F_1 **live oak x overcup hybrid.**

mediate in shape and size between those of the parents (Fig. 2). The trees hold half of their leaves through an average winter at College Station. In very mild winters they retain practically all of their leaves, but in unusually cold seasons the majority of these are dropped. This same tendency is approached in a lesser degree by live oaks.

The regular form, round top, good size, approach to evergreenness, and comparatively rapid growth rate, are all very desirable characteristics for hardwood trees. Combined as they are in the Ness Hybrids, it makes them valuable ornamental plants. They should add materially to landscape planting over the state if they could be successfully propagated and distributed.

A second generation population of 23 individuals started by Ness in 1923 is still growing at College Station. Three larger second generation (or F_2) populations, totalling about 326 plants, have been grown during the past 6 years by the senior writer of this article. Broad leaved, heavy foliaged, evergreen segregates are occasionally encountered in the second generation. Eleven plants, among the 326 recently grown, appeared especially promising and have been saved. Some of these are rapid growing and may prove to be even more desirable than the first generation Ness Hybrids. Some preliminary work indicates that methods, to be described later, for grafting of the F_1 Ness Hybrids would be equally applicable to desirable F_2 live oak × overcup oak hybrids.

STUDY OF METHODS OF PROPAGATION

During the past several years attempts to propagate the F_1 Ness Hybrids have been made and have now met with at least a measure of success. The methods of propagation used and the results secured are described in this paper. The first trials were with cuttings (4, 6). It would seem that if this hybrid material could be disseminated on its own roots that this would probably be the most satisfactory procedure. Attempts to propagate the hybrids on roots of other species by T-budding (4) have also been carried out. As the two sections in this paper dealing with cuttings and with T-budding will show, practically no success has followed the use of either of these methods. Propagation by grafting (5), however, has met with considerable initial success. Only time can tell how permanent the graft unions—and hence ultimate success of the propagation—will be. These grafts, made up of the first generation hybrid oak scions and of several different stocks, look promising enough at the present time that they are being sent out to interested nurseries. Trees grafted in 1940 have already been distributed and those grafted in 1941 will be available for future distribution; scion wood from the hybrid trees will be supplied where desired. It is thought that this material can thus serve as a source for further propagation and distribution by the several nurseries. By 1944 some trees should be available from nursery sources, and the supply should meet the ordinary demands in subsequent years.

Attempts to Root Cuttings

Numerous attempts have been made to propagate the hybrid oaks by rooting either stem or root cuttings. Various treatments have been given several thousand cuttings in such attempts. Cuttings were made at different times of the year, both from current season and also from one- and two-year old wood. The treatments and results are summarized in Table 1. Results have been consistently negative; no living plants have been secured so far from cuttings.

Different lots of cuttings were treated with the following growth promoting substance, or hormones: indolyl acetic acid, indole-3-N-propionic acid, γ-(indole-3)-N-butyric acid, naphthalene-acetic acid, and the commercial Hormodin A which contains γ-(indole-3)-N-butyric acid and Kak solutions.

The different chemicals were used in various concentrations and for treatment intervals varying usually from 24 to 72 hours depending to some extent upon the concentrations. It also may be noted from Table 1 that cuttings in some cases were treated with vitamin B_1 (1 part vitamin: 1 million parts water) both immediately following Hormodin A treatment, and at intervals following such treatment. This is essentially the method that was successfully used by Went et al (16) in the rooting of etiolated pea cuttings and leafy cuttings of lemon and of Camellia.

Treatments were given stem cuttings by soaking from one-half inch to one inch of the base in the hormone solutions. Root cuttings were either entirely immersed in aqueous solutions, or were bored and inserted with tooth picks which had been soaked with and contained the growth substances (approximately 2 mg. per pick) in crystalline form. This tooth-pick method was devised by Romberg and Smith (14) who have had success in stimulating the formation of new roots on transplanted pecans by its use.

Most cuttings were placed either in sharp white sand, or in a mixture of equal parts of this sand and peat moss; the lots were about equally divided between the two media. The large lots 1 to 6 and 1A and 2A (Table 1) were divided between four media. These included the two just mentioned and in addition red river-sand, and also a mixture of equal parts of red river-sand and peat moss.

Following a suggestion of Dr. C. L. Smith, of the U. S. D. A. Pecan Laboratory, Brownwood, Texas, callusing of cuttings prior to chemical treatment was attempted. This was done with the following lots listed in Table 1: 20A to 31, 33, 38 to 40, 57 to 60, and 136 to 144. It was found with oak material, as had Dr. Smith with pecan wood, that cuttings from dormant wood when placed in moist—not wet—sphagnum moss in a constant temperature oven at about 85°C. practically all callused heavily in from 1 to 3 weeks. Greenwood cuttings seldom callused by this method. A few of the callused cuttings both from untreated and from chemically treated lots produced weak root growth but the rooted cuttings all died.

A series of treatments using different growth substances in several powder or dust bases have been run with cuttings from live oak trees. The results, as with material treated in aqueous solutions, were all negative. On the basis of other experience with cuttings from live and from hybrid oaks we would anticipate similar negative results from the treatment of material from the hybrid forms with growth substances in powdered bases.

Discussion on Rooting of Cuttings

Available reports concerning attempted propagation of oaks by cuttings are not numerous. Hutchings and Larsen (8) failed to root cuttings of white oak following various chemical treatments. Bailey (2) mentions that evergreen species are occasionally increased by cuttings, but no details are given.

Thimann and Delisle (15) have arrived at some interesting results, concerning the rooting of cuttings from "difficult" plants, which may have an important bearing on the present work. They have pointed out that there are 3 groups of trees which are difficult to propagate by cuttings. These are: "(1) a majority of the conifers, (2) many forest hardwoods and (3) the apples and related rosaceous trees." A number of factors which might affect the rooting of cuttings were considered in their work. Among these were:

(1) The age of the tree from which cuttings were taken.
(2) Optimum auxin treatment.
(3) Relative rooting behavior of different parts of the plant.
(4) Rooting medium and temperature.
(5) Factors other than auxin such as sugar and vitamin B_1.

They found that "The most important single factor in rooting these 'difficult' trees is the age of the tree from which cuttings are taken. The ease with which roots are formed (on cuttings of one-year wood) falls off steadily with increasing age of the tree. This applies both in the presence and in the absence of auxin (hormone) treatment." In general it was found that cuttings from one-year old trees rooted well without auxin treatments; cuttings from 3 and 4 year old trees gave good rooting with optimum auxin treatments; but with a number of species cuttings from old trees could not be induced to root. This was true, among others, of cuttings from the Red Oak, *Quercus borealis*.

The work just cited confirms the work of Gardner (7) with respect to rooting cuttings of 1-year old plants. Further, it puts this observation, apparently, on a practical basis by advancing the rooting age of tree material up to 3 or 4 years—an age size from which several cuttings may be secured per plant—provided the proper auxin treatment is given.

McGinnis (9) has propagated live oaks by terminal cuttings from dormant wood of nursery, and hence fairly young trees.

Now the cuttings from the hybrid oaks used in the present instance were secured from the trees resulting from Ness' 1909 and 1910 crosses. Thus

Table 1. Summary of Unsuccessful Experimental Attempts to Root Cuttings of Hybrid Oaks.

Date cuttings were made	Lot Nos.	Chemical treatment (of cutting bases)	Total No. of cuttings	Bottom heat	Results
11-10-36	1-6	10 mg. indoleacetic acid per 100 cc. H_2O for 48 hours	1824	Yes	7 callused, 808 dead, 12-31-36. All dead 3-20-37. None rooted.
11-10-36	1-6	10 mg. indoleacetic acid per 100 cc. H_2O for 48 hours	326	No	4 callused, 164 dead, 1-1-37. All dead 5-1-37. None rooted.
11-10-36	1A, 2A	None	224	Yes	3 callused, 64 dead, 12-31-36. All dead 3-20-37. None rooted.
11-10-36	1A, 2A	None	32	No	11 dead 1-1-37. All dead 5-1-37. None rooted.
1- 3-37	12, 16, 20	None	144	Yes	All dead 3-1-37. None rooted.
1- 3-37	13, 17	5 mg. indoleacetic acid per 100 cc. H_2O for 52 hours	160	Yes	All dead 3-1-37. None rooted.
1- 3-37	14	10 mg. indoleacetic acid per 100 cc. H_2O for 44 hours	64	Yes	All dead 3-1-37. None rooted.
1- 3-37	15, 18	20 mg. indoleacetic acid per 100 cc. H_2O for 24 hours	160	Yes	All dead 3-1-37. None rooted.
1- 3-37	19	40 mg. indoleacetic acid per 100 cc. H_2O for 24 hours	100	Yes	All dead 3-1-37. None rooted.
2- 8-37	20A	"KaK" (solution), 24 hours	32	Yes	All dead 4-15-37. None rooted.
2- 8-37	20B	20 mg. indole-3-n-propionic acid per 100 cc. H_2O, for 20 hours	32	Yes	6 rooted, but all dead 4-15-37.
2- 8-37	20C	20 mg. indoleacetic acid per 100 cc. H_2O for 20 hours	32	Yes	5 rooted, but all dead 4-15-37.
2-23-37	20D	None	38	Yes	6 rooted, but all dead 4-12-37.
2-23-37	20E	"KaK" (solution), 24 hours	27	Yes	None rooted; all dead 4-12-37.
2-23-37	20F	10 mg. indoleacetic acid per 100 cc. H_2O for 24 hours	72	Yes	5 rooted, but all dead 4-20-37.
5-17-37	30	None	16	Yes	No callusing or rooting, all dead 6-10-37.
5-17-37	31	15 mg. gamma (indole-3)-N-butyric acid per 100 cc. H_2O for 24 hours	8	Yes	No callusing or rooting, all dead 6-10-37.
5-17-37	32	15 mg. gamma (indole-3)-N-butyric acid per 100 cc. H_2O for 24 hours	15	Yes	No callusing or rooting, all dead 8-4-37.
5-17-37	33	15 mg. gamma (indole-3)-N-butyric acid per 100 cc. H_2O for 24 hours	16	Yes	No callusing or rooting, all dead 8-4-37.
5-17-37	34	None	64	Yes	All dead 8-4-37. None rooted.
6-22-37	38	None (old growth, with leaves)	114	No	All dead 8-4-37. None rooted. All but 2 callused.
6-22-37	39	None (old growth, with leaves)	88	No	All started to callus, but none rooted. All dead 8-4-37.
6-22-37	40	None (current year's growth, with leaves)	43	No	All but 4 started to callus, but none rooted. All dead 8-4-37.
6-17-37	37[1]	10 mg. indoleacetic acid per 100 cc. H_2O for 24 hours	11	No	All dead 8-4-37. None rooted.
6-28-37	57[1]	5 mg. indole-3-N-propionic acid per 100 cc. H_2O, for 48 hours	4	No	All dead 8-4-37. None rooted.
6-28-37	58[1]	5 mg. gamma (indole-3)-N-butyric acid for 48 hours	4	No	All dead 8-4-37. None rooted.
6-28-37	59[1]	5 mg. indoleacetic acid per 100 cc. H_2O for 48 hours	4	No	All dead 8-4-37. None rooted.
6-28-37	60[1]	None	4	No	All dead 8-4-37. None rooted.
9-23-37	75	20 B.T.I. units Hormodin A, 24 hours	20	Yes	All but 2 dead 11-2-37. None rooted, all died.
9-23-37	76	10 B.T.I. units Hormodin A, 24 hours	20	Yes	All dead 12-24-37. None rooted.
9-23-37	77	10 B.T.I. units Hormodin A, 48 hours	20	Yes	All but 2 dead 12-24-37. None rooted. All died.
9-23-37	78	5 B.T.I. units Hormodin A, 24 hours	20	Yes	All dead 12-24-37. None rooted.

9-23-37	79	5 B.T.I. units Hormodin A, 48 hours	20	Yes	All dead 12-24-37. None rooted.
9-23-37	80	5 B.T.I. units Hormodin A, 72 hours	20	Yes	All dead 12-24-37. None rooted.
11-13-37	136	5 B.T.I. units Hormodin A, 24 hours	16	Yes	None rooted. All dead 3-5-38.
11-13-37	137	10 B.T.I. units Hormodin A, 24 hours	16	Yes	None rooted. All dead 3-5-38.
11-13-37	138	20 B.T.I. units Hormodin A, 24 hours	16	Yes	None rooted. All dead 3-5-38.
11-13-37	139	None	16	Yes	None rooted. All dead 3-5-38.
11-13-37	140	5 B.T.I. units Hormodin A, 48 hours	16	Yes	None rooted. All dead 3-5-38.
11-13-37	141	10 B.T.I. units Hormodin A, 48 hours	16	Yes	None rooted. All dead 3-5-38.
11-13-37	142	None	16	Yes	None rooted. All dead 3-5-38.
11-13-37	143	5 B.T.I. units Hormodin A, 96 hours	16	Yes	None rooted. All dead 3-5-38.
11-13-37	144	None	16	Yes	None rooted. All dead 3-5-38.
9- 7-38	166	10 B.T.I. units H.A., 24 hours, followed by vitamin[2] B_1 + 10 B.T.I., H.A., 48 hours	48	Yes	No rooting, all dying 12-8-38.
9- 7-38	167	10 B.T.I. units Hormodin A, 24 hours	48	Yes	No rooting, all dying 12-8-38.
9- 7-38	168	10 B.T.I. units Hormodin A, 48 hours. Vitamin[2] B_1 treatment, 24 hours, at once. Then after 2 months in the bench another vitamin[2] B_1 treatment—for 24 hours	72	Yes	No rooting, all dying 12-8-38.
10-22-38[4]	178	Benched 10-22. "Pick-treated"[3] 11-11, and then rebenched	15	Yes	
10-22-38[4]	179	None	15	Yes	
10-22-38[4]	180	20 B.T.I. units Hormodin A, 24 hours, 11-2-38	15	Yes	
10-22-38[4]	181	20 B.T.I. units Hormodin A, 38 hours, 10-22-38	15	Yes	None sprouted. All died.
10-22-38[4]	182	20 B.T.I. units Hormodin A, 38 hours, 10-22-38, vitamin[2] B_1 treatment, 24 hours, 11-2-38	15	Yes	
10-22-38[4]	183	20 B.T.I. units Hormodin A, 38 hours, 10-22-38, 20 B.T.I. units Hormodin A, 24 hours, 11-2-38	14	Yes	
11- 5-38[4]	184	Benched 11-5. "Pick-treated"[3] 11-11, and rebenched	15	Yes	
11- 5-38[4]	185, 187, 190	10 B.T.I. units Hormodin A, 24 hours	45	Yes	
					None sprouted in nursery. All died.
	186, 189	None	28	Yes	
	188, 191	10 B.T.I. units Hormodin A, 24 hours, 11-5, vitamin[2] B_1 treatment 36 hours	72	Yes	
	192	10 B.T.I. units H.A. + vitamin[2] B_1, 24 hours.	15		
1-13 and 19/39[4]	248	"Pick-treated"[3], indolebutyric acid, 3-25-39	80	No	All in good condition 3-27-39. Check 4-17-39, showed that most started to swell and callus around toothpick but none sprouted. All died.
	249	"Pick-treated"[3], indoleacetic acid, 3-25-39	80	No	
	250	"Pick-treated"[3], napthalenacetic acid, 3-25-39	85	No	
	251	"Pick-treated"[3], indole-3-N-propionic acid, 3-25-39	70	No	

[1]Live oak cuttings.
[2]Concentration of the vitamin B_1 solution was 1 part in 1,000,000 parts of H_2O.
[3]Pick-treated after Dr. C. L. Smith's method with enough indoleacetic acid to allow 2 mgs. per pick.
[4]Root cuttings.

they were from trees between 25 and 30 years of age. The obvious implication, from the work of the investigators mentioned above, is that the age of these trees is a limiting factor virtually preventing rooting of cuttings from them when treated by known methods. To overcome this handicap the live × overcup oak cross, first made by Ness, has been repeated. Several young seedlings are now available as sources for cuttings—which may possibly be induced to root by proper treatments.

Attempts to Propagate by T-Buds

Over a period of four years several hundred buds from the first generation hybrid oaks have been T-budded into young stock of several oak species and hybrids. In 1938 buds were inserted in August. In 1939 and 1941 budding was done during May. In 1940 the buds were inserted during October, with the thought that these might unite before growth ceased in the fall, and after remaining dormant over winter could be forced into

Table 2. Number of hybrid oak T-buds inserted in several stocks at different times of the year, with negative results.

Oak stocks[1] (acorns from open pollinations)	Time of bud insertion				Total
	August 1938	May 1939	October 1940	May 1941	
Burr	----------	15	23	----------	38
Chinese	15	15	17	10	57
Live	10	15	----------	25	50
Overcup	5	10	10[2]	----------	25
Pin	5	5	6	----------	16
Post	----------	10	9	----------	19
Spanish	----------	5	2	----------	7
Water	10	10	8	----------	28
Willow	----------	----------	4	----------	4
F_2 (Live × Overcup)	10	15	20	----------	45
F_3 (Live × Overcup)	----------	----------	11	----------	11
F_2 (Live × Swamp White)	20	15	26	15	76
Total	75	115	136	50	376

[1]See next section, "Propagation by Grafting," for scientific names of the various stocks.
[2]One bud from this lot produced a tree.

growth in the spring. A summary of the number of buds inserted, at different times and on several stocks, is given in Table 2. Results have been almost entirely negative. One bud inserted on an overcup oak whip in October 1940 united and has grown into a young tree. This was the only bud, out of 376 set, to unite and grow.

The reason for the failure of the T-buds is not known. The bark of the stock slipped well when the budding was done. The buds were inserted with only a very thin sliver of wood included. The technique used in the budding appeared, and was considered, satisfactory. When the rubber bands used for tying were removed at the end of 10 days a large per cent of the buds were green in color and appeared to be alive. Usually inspection after 4 or 5 weeks revealed the same condition. But after that the stock bark started curling back, allowing the bud to drop out. Inspection of a number of buds was made after 4 weeks; if any callusing had occurred it was difficult to identify by macroscopic examination. The buds apparently remained green in color for same time but without anatomical union taking place.

Propagation by Grafting

The desirability of attempting graftage was emphasized when the negative results with cuttings and with the first bud insertions became apparent.

Stocks

Stocks for possible grafting or budding were already being grown from acorns secured in the fall of 1936, 1937, and 1938. The acorns were stratified from time of gathering until planted in the nursery about the first of January following collection.

The oaks used as stocks, with their relationship in the genus *Quercus* according to Rehder (13) are as follows:

Subgenus II. Erythrobalanus—Black oaks (acorns mature the 2nd year).
Quercus nigra L. (Water O.)
Q. marilandica Muenchh. (Black Jack)
Q. rubra L. (Spanish O.)
Q. palustris Muenchh. (Pin. O.)

Subgenus III. Lepidobalanus—White oaks (acorns mature the first or second year).
Section 1. Cerris (Fruit biennial.)
Q. serrata Sieb. & Zucc. not Thumb. (Chinese O.) (fruit usually ripens the first year in Texas)
Section 3. Ilex. (Fruit usually annual)
Q. virginiana Mill. (Live O.)
Section 6. Prinus (Fruit annual)
Q. alba L. (White O.)
Q. stellata Wangh. (Post O.)
Q. lyrata Walt. (Overcup O.)
Q. macrocarpa Michx. (Burr O.)
Q. bicolor Willd. (Swamp White O.)

The first four of these fall in the group commonly designated black or pin oaks, the last six belong to the class often collectively called white oaks. Bailey (2) uses the terms black oaks and white oaks to designate the collective species in the subgenera Erythrobalanus and Lepidobalanus, respectively. The Chinese oak, representing the extreme of the subgenus Lepidobalanus nearest the black oaks resembles the latter group in several morphological characters and in grafting behavior with the Ness Hybrid scions. In the discussions of this paper it is considered, for convenience, along with the black oaks. Most of the species used are Texas natives. *Quercus palustris and Q. bicolor* approach, but do not often occur within the borders of the state. The Chinese oak, as its name suggests, has been brought to this country from the Orient. In addition to the pure species, seedling stocks derived from two of Ness' hybrids have been used. These latter are second generation (or "F_2") open-pollinated seedlings of the crosses live oak × overcup oak, and live oak × swamp white oak.

Acorns of the native forms are usually available. If desired for stock seed they should be gathered as soon after ripening as possible and then within a few days, should be stratified in moist sand, or planted in nursery rows where they will remain moist. Acorns properly treated usually produce excellent seedling stands, but seed of many oaks germinate very poorly if allowed to air dry for even a few weeks.

Graftwood

With the methods of grafting followed in this experiment it is customary to use one-year-old scions. Normally these should be about three-eights of an inch in diameter. Preferably they should be straight and unbranched. The Ness Hybrids do not produce such scions abundantly. Their growth habits, in mature trees especially, often result in branching before the limbs attain suitable size. Some of the available scions were straight, unbranched shoots of 1-year-old wood; others were of 2-year-old wood. When the latter type was used, care was taken to leave a 1-year-old side branch on each scion if possible. Some scions consisted of a 2-year-old base and a 1-year-old terminal portion. At the point of mergence of the 1- and 2-year-old woods there were formed numerous buds which developed and grew satisfactorily under favorable conditions.

The scions were cut each year during February, while the trees were still dormant. They were then packed in moist sphagnum moss and kept in cold storage until used for grafting. The temperature of the storage vault ranged from 34° F. to 40° F.

Grafting Methods Used

Whip Graft.—This method was used mainly on rootstocks which were from ½ to ¾ inch in diameter. Soil was removed from around the bases of the seedling stocks and the grafts were inserted slightly below the ground level. They were tied with cotton twine; no waxing material was used. Finally, moist soil was pressed closely about the graft leaving only the tip exposed.

Bark Graft and Inlay Graft.—These two methods are quite similar. Results of the few inlay grafts made are tabulated with those of bark grafts. Usually stocks that were about 1-inch in diameter were used for these grafts. Generally they were set within one foot of the ground. They were tied with cotton twine and either grafting wax or melted paraffin was applied in order to exclude air from all open surfaces and prevent drying.

Some of the stock species could not be grafted readily by either of these two methods, because of the difficulty encountered in getting the bark to separate from the wood. This was particularly true of water oak, 2- and 3-year old burr oak, and Chinese oak stocks.

Cleft Graft.—This method likewise was used on stocks that were 1-inch, and often larger, in diameter. Grafts were usually set within 1 foot of the ground. Cleft grafts were also tightly tied with cotton twine, and covered with grafting wax or melted paraffin.

Detailed description of the general grafting, as well as budding, methods used in the present work may be found in numerous books and bulletins including those of the United States Department of Agriculture (3, 12).

As the grafts produced growth and were in danger of mechanical or wind breakage they were staked with laths and tied up periodically. Until mid-summer the grafts were inspected about every 10 days for (1) removal of stock buds and shoots, (2) rewaxing where necessary, and (3) additional tying when growth warranted. After about July 15 a check on these points was made every 15 or 20 days during the growing season. The strings tying the grafts in place were removed before the stock diameter increased enough for damage from girdling to occur. Rainfall was much above average both in 1940 and 1941. In seasons of lighter rainfall lower growth rates might not necessitate such frequent checks.

PRESENTATION AND DISCUSSION OF GRAFTING DATA

Comparison of Methods

The percentage of grafts which live and grow appears the most obvious criterion for determining the initial value of a grafting method or of the kind of stock used. On this basis, reference to the percentage figures in the lowest row of Table 6 offer a ready comparison of the grafting success resulting from the three methods used. Fifty-nine per cent of all whip grafts and 68 per cent of all bark grafts, but only 20 per cent of the cleft grafts made, were successful.

From Table 3 it may be seen that of the grafts made in 1940 the whip grafts were considerably the most successful on a percentage basis. The data of Table 4 show that the whip grafts made in 1941 were again quite successful. But in the latter year even greater success resulted from use of the bark graft method; this point is discussed further in the next paragraph.

A comparison of summary figures in Tables 3 and 4 shows a much higher percentage of bark grafts to have been successful in 1941 than in 1940. In 1940 all bark grafts were made just after the sap started to flow but before many buds had burst. At that time difficulty was encountered in getting bark to "slip" without stringing. In 1941 the majority of the bark grafts were made some two weeks after leafing began, and at that time the bark slipped cleanly on many of the stocks. The disparity in percentage of unions in the two years can apparently be traced directly to this difference in ease of working the bark on the different occasions. When making bark grafts with oaks, then, it would seem wise to delay insertion until well after stock dormancy has broken. The scions, of course, should be held dormant until used.

The percentage of successful cleft grafts was low in 1940 and still lower in 1941. As pointed out earlier most wood used for cleft grafts in the present work has been above an inch in diameter. It was observed that where ideal fits were secured with most stocks that a high proportion of cleft grafts united. But such fits were difficult to fashion. It has seemed obvious that size and hardness of the wood used, resulting in many poor fits between stock and scion, have been responsible for the unfavorable results in many cases. The use of wood of smaller diameter would probably make for closer fit and increased success with the cleft type of graft.

Despite results from bark grafting in 1940 it seems apparent that both whip and bark grafting are methods that will give a high percentage of successful unions with compatible stocks. Cleft grafting, at least with larger sized stocks, is a less successful method.

Table 3. Summary of 1940 grafts to August 15, 1941—17 months after grafting.

Oak stocks	Whip			Cleft			Bark			Total			Total avg. height (inches)
	Made	Alive	Per cent alive	Made	Alive	Per cent alive	Made	Alive	Per cent alive	Made	Alive	Per cent alive	
Burr	29	26	89.7	—	—	—	—	—	—	29	26	89.7	43.3
Live	1	1	100.0	3	1	33.3	2	1	50.0	6	3	50.0	64.3
White	2	2	100.0	—	—	—	—	—	—	2	2	100.0	39.5
F_2 (Live × Overcup)[1]	4	3	75.0	1	1	100.0	1	0	0.0	6	4	66.7	46.0
F_2 (Live × Sw. White)[1]	31	30	96.8	4	2	50.0	2	0	0.0	37	32	86.5	46.2
Black Jack	10	0	0.0	—	—	—	—	—	—	10	0	0.0	—
Chinese	33	4	12.1	4	1	25.0	8	1	12.5	45	6	13.3	41.2
Water	9	1	11.1	9	1	11.1	7	3	42.9	25	5	20.0	44.4
Totals	119	67	56.3	21	6	28.6	20	5	25.0	160	78	48.7	45.2

[1]From open pollinated acorns.

Comparison of Stocks

1940 Grafts

The data for the grafts made in 1940 are summarized in Table 3. Out of a total of 162 grafts made, 2 were injured mechanically and are not included here.

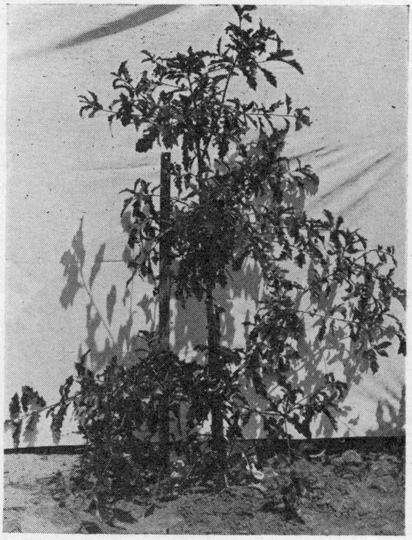

Figure 3. Ness Hybrid oak grafts on F_2 (live oak x swamp white oak) roots. Whip graft made March 18, 1940. Picture taken July 26, 1941.

On a percentage basis the two outstanding stocks used in 1940—where 10 or more grafts were made on similar stocks—were burr oak and the hybrid F_2 (live × swamp white) oak (Fig. 3). Favorable percentages of successful stock combinations were also secured, from a smaller number of grafts, between hybrid scions and seedlings of the F_2 (live × overcup), live oak (Fig. 4), and white oak *(Q. alba).* Only a small percentage of the grafts on Chinese and water oaks grew, and none of those on black jack were successful.

All living grafts were measured for height on August 15, 1941. On that date 78 trees living from the 17-month old 1940 grafts averaged 45.2 inches The figures for all cleft, bark and whip grafts were 63.5, 50.0, and 42.6 inches, respectively. Bark and cleft grafts had been made as near the ground as convenient, but the stock stubs did give these two types of grafts some height advantage. Not all the height difference between the trees from the cleft and whip grafts can be accounted for in this way, however. In general the smaller stocks were used for whip grafts, the largest for cleft grafts, and bark grafts were made on stocks intermediate in size between the other two. It is possible that the greater food reserves in the larger stocks account for at least part of the superior size of the scions they bear.

Figure 4. **Ness Hybrid oak grafts (2 plants to the right) on live oak roots, compared with a seedling live oak (to the left). The hybrid scions were cleft grafted on March 18, 1940. The photograph was made July 26, 1941. The live oak seedlings, as well as the seedlings used here for stocks, were all placed in the nursery about January 1, 1938. The tree to the right shows a water sprout starting from the rootstock; these need to be removed frequently until the grafts get a good growth start.**

1941 Grafts

Table 4 summarizes data on the 1941 grafts. It is seen that all of the kinds of stocks used in 1940 were used for additional grafts in 1941. Also seedlings of post, overcup, swamp white, and in a few cases of pin and Spanish oaks furnished stocks for other 1941 grafts.

It is evident from the table that more than 60 per cent of the hybrid scions lived on each of the following stocks: post, F_2 (live $\times$ swamp white), swamp white, live (Fig. 6), burr, overcup (Fig. 7), and black jack. Only 3 grafts were made on black jack, not enough for a reliable test. About 65 per cent of the grafts made on the F_2 (live $\times$ overcup) seedlings grew (Fig. 5). Grafts on white oak *(Q. alba)* were not as successful as the few made in 1940. Poor results were again obtained with grafts on Chinese and water oaks.

Figure 5. **A Ness Hybrid oak graft on roots of an open-pollinated F_2 (live x overcup) oak seedling. Bark grafted on April 10, 1941. The picture was made September 1, 1941, at which time this graft was 58 inches in height.**

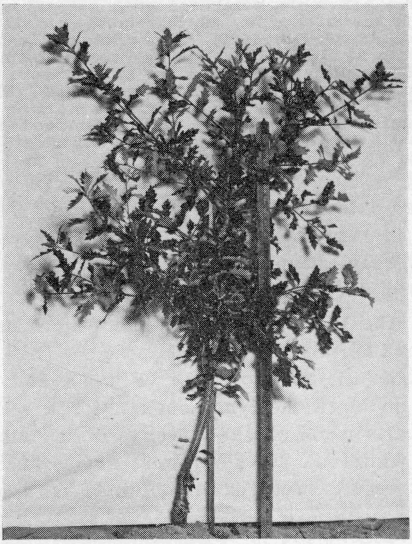

Figure 6. **Ness Hybrid oak graft on live oak roots. Bark graft made in early April, 1941. Photograph made September 1, 1941.**

Table 4. Summary of 1941 grafts to August 15, 1941—4 months after grafting.

Oak stocks	Whip			Cleft			Bark			Total			Total avg. height (inches)
	Made	Alive	Per cent alive	Made	Alive	Per cent alive	Made	Alive	Per cent alive	Made	Alive	Per cent alive	
Burr	14	9	64.3	—	—	—	—	—	—	14	9	64.3	29.6
Live	7	2	28.6	2	0	0.0	20	19	95.0	29	21	72.4	30.9
Overcup	1	1	100.0	5	3	60.0	15	9	60.0	21	13	61.9	43.6
Post	15	15	100.0	4	4	100.0	14	13	92.9	33	32	97.0	33.9
Swamp White	—	—	—	—	—	—	14[2]	14	100.0	14	14	100.0	46.9
White	1	1	100.0	—	—	—	3	0	0.0	4	1	25.0	12.0
F_2 (Live × Overcup)[1]	7	5	71.4	10	0	0.0	14	12	85.7	31	17	54.8	39.4
F_2 (Live × Sw. White)[1]	1	1	100.0	1	0	0.0	11	11	100.0	13	12	92.3	43.3
Black Jack	3	2	66.7	—	—	—	—	—	—	3	2	66.7	22.0
Chinese	10	4	40.0	16	0	0.0	9	6	66.7	35	10	28.6	31.6
Pin	4	2	50.0	—	—	—	—	—	—	4	2	50.0	8.5
Spanish	2	0	0.0	—	—	—	—	—	—	2	0	0.0	—
Water	—	—	—	32	5	15.6	10	0	0.0	42	5	11.9	33.0
Totals	65	42	64.6	70	12	17.1	110	84	76.4	245	138	56.3	36.0

[1]From open pollinated acorns.
[2]These were really inlay grafts, rather than the usual type of bark grafts.

Table 5. Combined summary of 1940 and 1941 grafts, on similar stocks, to August 15, 1941.

Oak stocks	Whip			Cleft			Bark			Total			Total avg. height (inches)
	Made	Alive	Per cent alive	Made	Alive	Per cent alive	Made	Alive	Per cent alive	Made	Alive	Per cent alive	
White Oaks:													
Burr	43	35	81.4	—	—	—	—	—	—	43	35	81.4	39.8
Live	8	3	37.5	5	1	20.0	22	20	90.9	35	24	68.6	35.1
White	3	3	100.0	—	—	—	3	0	0.0	6	3	50.0	30.3
F_2 (Live × Overcup)[1]	11	8	72.7	11	1	9.1	15	12	80.0	37	21	56.8	40.6
F_2 (Live × Sw. White)[1]	32	31	96.9	5	2	40.0	13	11	84.6	50	44	88.0	45.4
Black Oaks:													
Black Jack	13	2	15.4	—	—	—	—	—	—	13	2	15.4	22.0
Chinese	43	8	18.6	20	1	5.0	17	7	41.2	80	16	20.0	35.2
Water	9	1	11.1	41	6	14.6	17	3	17.6	67	10	14.9	38.7

[1]From open pollinated acorns.

On August 15, 1941, the 138 trees living from the 4-month old 1941 grafts averaged 36 inches in height. The respective averages for bark, cleft, and whip grafts were 42.2, 38.9, and 22.6 inches.

Figure 7. Ness Hybrid oak grafts on overcup oak stock. Bark grafts made April 10, 1941. Photograph made July 26, 1941. Note method of tying, and that much of the twine on the two grafts to the left is hidden by the waxing material. The plants have been staked and loosely, but securely, tied to prevent wind damage prior to formation of a firm graft union. All stock sprouts had been removed on July 17. Many new sprouts were taken from the stocks before this picture was made, but the long one extending upward (to the right) from the stock of the right hand plant was left to show how rapidly these sometimes grow during wet periods. It is easy to see that if many of these were left on the stock very long that the scion would suffer as a result.

1940 and 1941 Grafts Considered Together

Table 5 and, more especially, Table 6 present the data of Tables 3 and 4 in combined form. The discussion that went with the two preceding tables applies, in general, here, and this, together with the combined data makes certain conclusions seem apparent.

There are 4 stocks on which more than 80 per cent of the grafts made are alive. These are post, F_2 (live × swamp white), burr, and swamp white. Also 56 per cent or more of the grafts made on stocks of live, overcup, and F_2 (live × overcup) are thriving. Thus there are 7 stocks on which the hybrids scions may be said to have made a good to excellent growth. The other stocks used have either resulted in a low percentage of unions or have had too few grafts made on them to indicate their value correctly.

Table 6 presents a summary, derived from Tables 3 and 4, of the combined grafting results with all white oak stocks, as compared with the results from all black oaks used as stocks. A consideration of some of the

Table 6. A comparison of number of grafts made (according to type), and the number and percentage that were successful, on all white oak and on all black oak species, respectively.

Grafts on	Kinds of grafts				
	Whip	Bark	Whip and bark	Cleft	All grafts
White oak stocks					
Number made	113	96	209	30	239
Number successful	96	79	175	11	186
Per cent successful[1]	85	82	84	37	78
Black oak stocks					
Number made	71	34	105	61	166
Number successful	13	10	23	7	30
Per cent successful[1]	18	29	22	12	18
White + black oak stocks					
Number made	184	130	314	91	405
Number successful	109	89	198	18	216
Per cent successful[1]	59	68	63	20	53

[1]All percentages expressed to nearest whole number.

data of Table 6 shows some interesting comparisons between results with white and with black oak stocks. Of the 113 whip grafts on white oak species 96, or 85 per cent, were successful. Only 18 per cent of the 71 whip grafts on black oaks have grown. With respect to bark grafts 79 of 96, or 82 per cent have been successful on white oaks, but only 10 of 34, or 29 per cent on black oaks. Thirty-seven per cent of all cleft grafts on white oaks, but only 12 per cent of this type on black oaks, grew.

It is of further interest to consider all bark and whip grafts together. Two hundred nine of these types of grafts were made on white oaks, and 175, or 83.7 per cent, of these were successful. Only 22 per cent of the grafts of these two types made on black oaks grew.

It appears then that the live × overcup hybrid grafts readily on the closely related white oaks used as stocks, but with little success on the genetically more remote black oaks.

A worthwhile comparison may be made of data in the percentage columns of Tables 3 and 4. In most cases where as many as 10 grafts per type were made these percentages of living grafts run rather close together in the two tables. Where they do deviate considerably it is usually with the poorer, or black oak, stocks where a larger percentage of 1941 grafts, than of the 1940 ones, are apt to have been alive in August 1941. Table 7 gives a comparison of 1940 grafts alive on white oaks and also on black oaks on several subsequent dates. The arrangement

Table 7. Grafts made in 1940 on white oaks as compared with those on black oaks, with respective numbers alive on several subsequent dates.

Type of Stock	No. of grafts made March 18 and 20, 1940	Grafts alive 4-19-40		Grafts alive 4-11-41		Grafts alive 8-15-41	
		Number	Per cent[1]	Number	Per cent[1]	Number	Per cent[1]
White oak	80	72	90	69	86	67	84
Black oak	80	61	76	20	25	11	14
Total	160	133	83	89	56	78	49

[1]Percentages are stated in nearest whole numbers.

of the data in Table 7 brings out clearly that the percentages in Tables 3 and 4 for total number of grafts alive by certain dates, have been materially lowered by including consideration of the black oak group. There is a consistent significant decrease in number of viable grafts on black oak stocks. It is evident that on black oaks there is not only a lower percentage of initial successes, but those grafts which do start off are subject to a higher death rate during the first and second seasons than is the case for the more compatible stocks. The decrease in number of good grafts on white oaks, however, is scarcely more than might be expected from mechanical injuries.

Microscopic Examination of Graft Unions

Results show that the Ness Hybrids can be grafted readily and successfully on certain stocks, but not so easily upon others. At the end of one season's growth (in 1941) microscopic examination was made of bark graft unions of the hybrids with live oak, Chinese oak, seedlings from open-pollinated acorns of the live × swamp white oak cross, post oak, and overcup oak; also of whip graft unions with burr, and Chinese oaks.

The sections were cut from fresh material, approximately 30 microns thick, stained with safranin and gentian violet, and mounted in balsam.

Only a limited number of graft unions were sectioned. Two bark graft and one whip graft union of the Ness Hybrids on Chinese stock, and only one graft union on each of the other stocks listed above were sectioned. The grafts on the Chinese oak stocks, selected for microscopic study, were the most vigorous and promising available; they were slightly over 3 feet in height. Individuals as representative as possible of the other available stocks were chosen. Hence, while these limited observations cannot be regarded as necessarily representative, it is believed they do give a rather reliable indication of the union occurring between the hybrids and the two general types of stocks (i.e., black and white oaks).

Sections of the union of the hybrid with live oak and with overcup oak (Fig. 8) show that the scion and stock each produced callus tissue from the cambium in considerable quantity. It is apparent from the position of the points, X and X^1, at which union first took place, that this process occurred soon after the graft was made and callus formation had begun. The lines of union, XY and X^1Y^1, that resulted from the subsequent growth of the scion and stock were smooth, with no evidence of incompatibility.

Prepared sections through unions of the hybrid on post, burr, and the F_2 (live × swamp white) oak stocks likewise indicated a free formation of callus by the two components and a ready union of the new tissues.

Sections of the hybrid on Chinese oak indicated that initial union was inhibited (Fig. 9). There is evidence here that the stock and scion each produced the necessary callus. The calluses from the two, however, apparently did not always unite when they first came in contact. Sec-

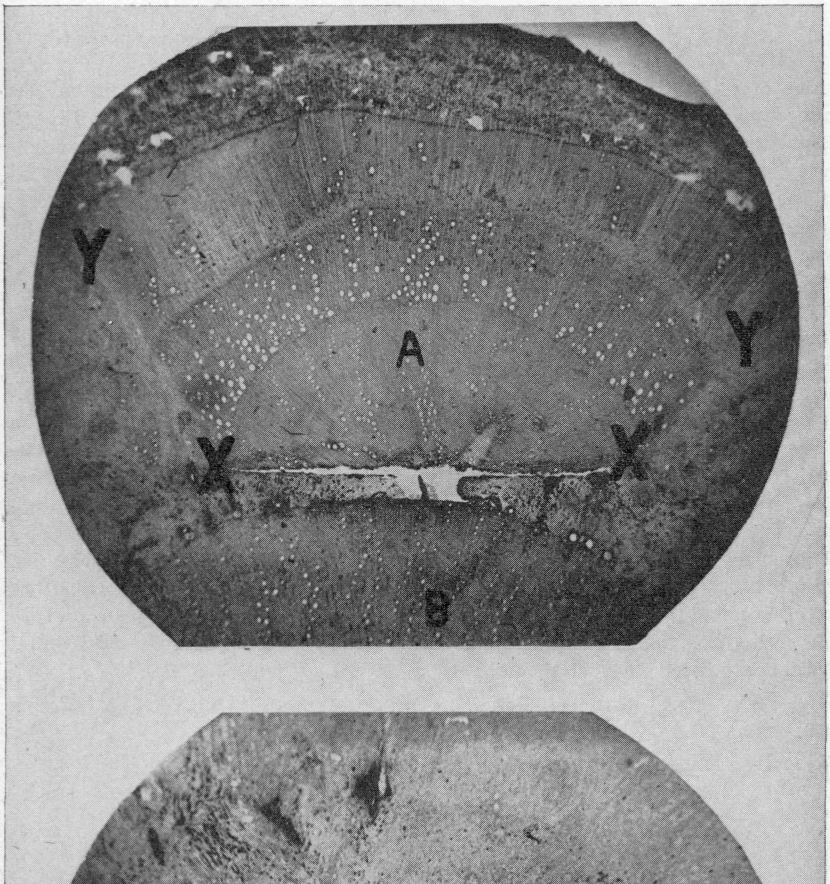

Figure 8. **Cross sections of bark grafts of Ness Hybrid oak on live oak (above) and on overcup (below). X10.8. Note that union first occurred at X and X[1]. The lines X to Y and X[1] to Y[1] indicate a good strong union between stock (B) and scion (A).**

tions of one bark graft. (Fig. 9, above) showed that the line of union was not continuous after union was first established. There is definite evidence of periderm along the surface of the first-formed callus, particularly of that from the stock. This might have been due to poor technique in inserting the graft, to inadequate waxing and subsequent exposure to air, or to some substance peculiar to the stock species. The latter is suggested to be the case since it appeared that the periderm had formed more fully upon the callus from the stock, than upon that of the adjacent scion. It is noteworthy further that calluses from different parts of the stock formed periderm and did not unite readily when they came in contact. Sections from the other two grafts studied (one of which is shown in Fig. 9, below) show a good union with nothing to indicate incompatibility between the stock and scion after union took place. These observations suggest that the chief difficulty in grafting Chinese oaks may be in obtaining the initial union of callus from the stock with that from the scion. Any delay in this process, though it may be slight, results inevitably in loss of vitality of the scion and decreases its chances of ultimate union. Observations of the sections, coupled with field behaviour of the grafts, suggests that the prevailing stock-scion incompatibility with the black oaks is more often due to physiological reasons than to failure of anatomical union. Additional data are needed to verify this.

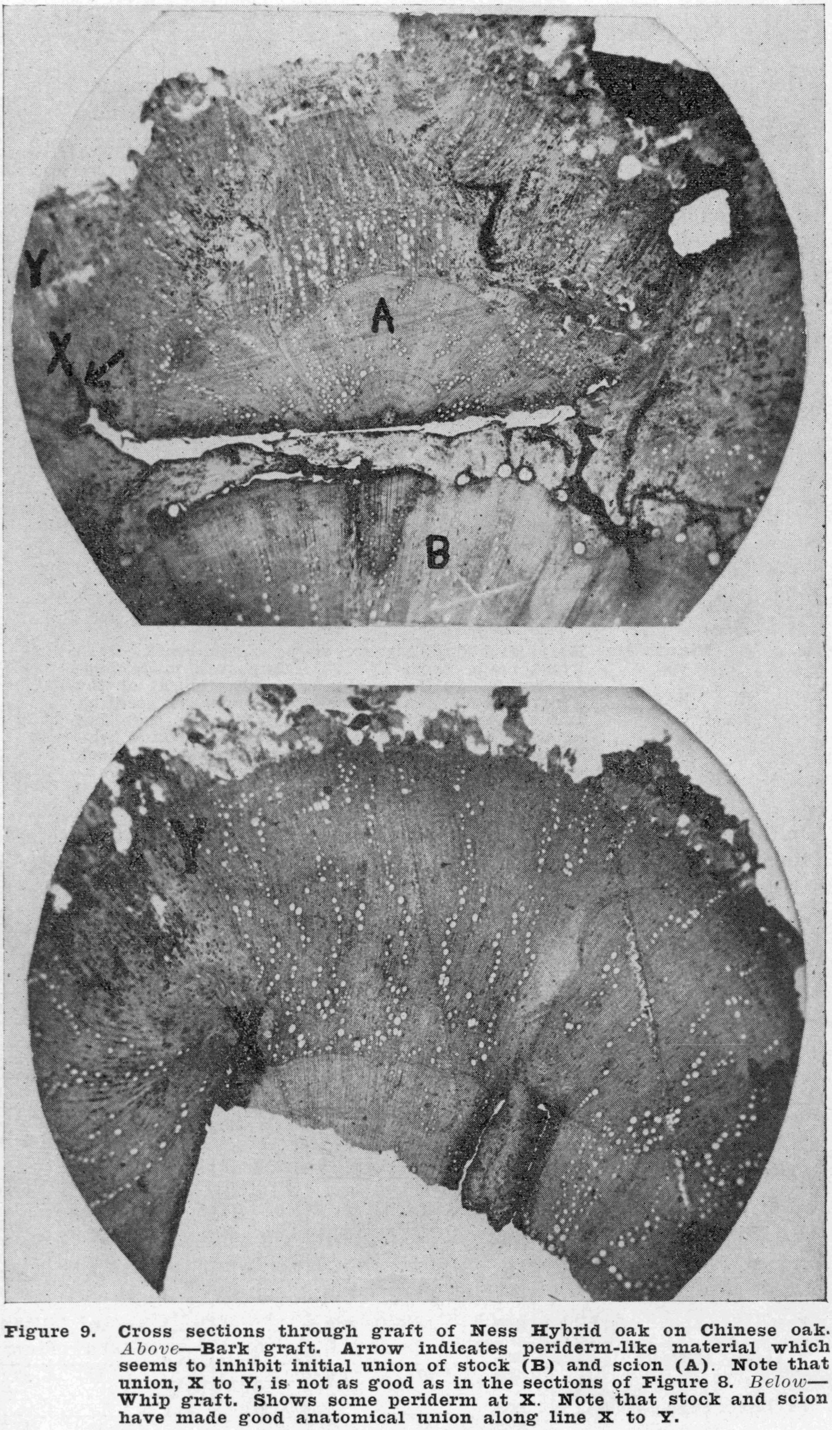

Figure 9. **Cross sections through graft of Ness Hybrid oak on Chinese oak.** *Above*—**Bark graft. Arrow indicates periderm-like material which seems to inhibit initial union of stock (B) and scion (A). Note that union, X to Y, is not as good as in the sections of Figure 8.** *Below*—**Whip graft. Shows some periderm at X. Note that stock and scion have made good anatomical union along line X to Y.**

Heights of Grafts and of Ungrafted Seedling Stocks Compared

A number of ungrafted nursery seedlings of several kinds of oaks were measured for height in mid-August 1941. All of these were put in the nursery as acorns or very young seedlings about January 1, 1939.

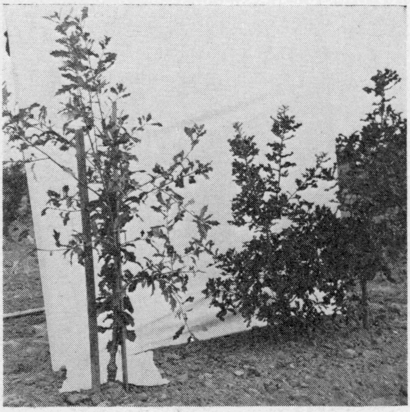

Figure 10. Ness Hybrid oak graft on post oak roots. Bark graft made April 17, 1941. Exposure made September 1, 1941, at which time the height of the graft was 52 inches, that of the post oak seedling immediately behind it was 39½ inches, and that of the post oak seedling in the background was 44 inches. All seedlings, whether used for stock or otherwise, were set in the nursery about January 1, 1939, from acorns gathered in the fall of 1938.

In Table 8 a comparison can be made between the heights of these seedlings and of grafts which have been made on other seedling stocks of the same kind and set at the same general place and time.

Table 8. Heights of oak seedlings, compared with heights of hybrid scions grafted on stocks of the same species (all measurements were made in inches August 14 and 15, 1941).

Stocks	Date of setting stocks in nursery[1]	Seedlings		Grafts 1940		Grafts 1941	
		No. measured	Avg. height	No. measured	Avg. height	No. measured	Avg. height
Burr	1939	72	29.2	26	43.3	9	29.6
Chinese	1938	-----	-----	6	41.2	-----	-----
	1939	79	48.3	-----	-----	10	31.2
Live	1938	-----	-----	3	64.3	5	33.5
	1939	8	34.4	-----	-----	16	30.1
Overcup	1938	-----	-----	-----	-----	10	43.1
	1939	1	30.0	-----	-----	3	45.0
Post	1939	59	28.3	-----	-----	33	33.9
F_2 (Live × Overcup)	1938	-----	-----	4	48.0	-----	-----
	1939	27	37.5	-----	-----	17	39.4
F_2 (Live × Swamp White)	1938	-----	-----	37	46.2	-----	-----
	1939	42	31.2	-----	-----	12	46.3

[1]About January 1 of each year.

Some of the grafts were made on stocks set in a slightly different location early in 1938. Where such grafts were made on stocks of the kind measured, height data from them is also given in Table 6, although there are no comparable figures on seedlings.

At the time of measurement the average height of grafts made either in 1940 or 1941 was greater than that of comparable seedlings—set in 1939—in most cases (Fig. 10). Seedling live oaks were somewhat, but probably not significantly, taller than grafts made on such stocks (Fig. 4). The other exception is with Chinese oaks where the seedlings were markedly taller (Fig. 11) than the grafts on stocks of this oak.

Of the kinds of seedlings available for measurement all but the Chinese oak have been indicated, by the evidence presented earlier in the paper, to be good to excellent stocks for the hybrid scions. The available data on height and grafts seems, then, to fall in line with conclusions arrived at in previous sections of this paper.

Figure 11. Comparison of 1940 Ness Hybrid oak graft (to the right) with a seedling Chinese oak. The propagation was by whip grafting on March 20, 1940. Exposure was made September 1, 1941. Some of the branches on the right side of the seedling were removed so as not to hide parts of the graft. Seedlings were from January 1, 1939, nursery planting. Compare with figures 4 and 10 where the grafts were made on stocks of the white oak type.

General Discussion on Grafting

It would have been desirable for purposes of statistical analysis to make the same number of insertions of the three types of grafts on each stock used. This was the original plan, but it could not be entirely followed for several reasons. Percentage and time of acorn germination limited the total number of seedlings of some stocks, and in turn the number available for certain types of grafts in other cases. Then too the grafts were made by several persons and on different days. Hence both the personal element and also differences in physiological responses of the plants at differents times (as, perhaps, witness the difference in results with bark grafts in the 2 years) were pertinent factors. Such factors could not very well be eliminated and while present were bound to affect the outcome. It appears, however, that the results are clean cut enough to recommend definitely the types of grafts and the kinds of stocks to be used to secure practical success, at least initially, in propagating the hybrid oaks. As a corollary—the results also show some stocks, and perhaps one grafting method to avoid.

The work of Armstrong (1) in grafting the live oak upon the post oak should be mentioned. He reported 84.7 per cent of his bark grafts, 35 per cent of cleft grafts and 0.00 per cent of whip grafts made as being successful. His work was carried out as an undergraduate student problem, and the data upon which the report was based were taken about one month after the grafts were made. While 92 per cent of the patch buds and 81 per cent of the chip buds placed were alive 3 weeks later, the author pointed out that the data regarding buds was not to be relied upon due to the small number used and the shortness of elasped time from placement to recording of final data. Armstrong's work gave strong evidence, since verified by time, that the live oak will unite with, and grow upon, the post oak.

Factors Favoring Success of Stocks

The results show that the Ness Hybrid Oaks may be successfully grafted on white oak stocks, but that the black oak species used as stocks are in general incompatible. Several factors may account for the difference of results with these two groups of stocks, but probably all can be traced to the degree of relationship existing between the scion and the stocks.

It would seem probable that the type of bark and wood in 2 and 3 year old stocks might have an effect on grafting results within each group. Among the white oaks live, overcup, white, swamp white, and the F_2 hybrids of live $\times$ swamp white, and live $\times$ overcup all have thin easily worked bark covering wood that is usually smooth. Post oak, however, while having similar bark, has underlying wood that is quite wavy and irregular in outline. If undulating wood has an unfavorable effect on grafting success with this species, however, it is not shown in the ,first year's results. Burr oak has smooth bark the first year, but not many seedlings are large enough for grafting then. In later years it has very rough bark, covering irregularly outlined wood—a discouraging combination especially for bark grafting. Among the black oaks we find Chinese oak with very thick bark containing heavy conducting vessels and covering rough wood, and at the other extreme the water oaks with thin pliable bark covering smooth wood. Ease of grafting is certainly influenced by the type of bark and wood encountered, and this is very likely to be reflected in the percentage of successful grafts secured.

There are differences in the hardness or toughness of wood of the different stocks. Chinese oak for instance has a very hard wood difficult to cut in even planes. Burr oak wood on the other hand, while hard, has a more even grain, facilitating the making of smooth surfaces.

The dividing crown encountered in live oak seedlings makes this form relatively unfavorable for whip grafting. The swollen part of the root or crown above the division is usually the only underground part large enough to be suitable, and it has a tendency to be soft, and sometimes almost pithy—factors making the cutting of smooth planes rather difficult.

SUMMARY

1. First generation hybrid oaks produced by the late Helge Ness from the cross of live oak × overcup oak have characters making their propagation and dissemination desirable. They have a rounded symmetrical shape, approach the evergreenness of the live oak, the habit of the overcup oak, and have a higher growth rate than either parent.

2. A wide series of treatments of cuttings from the original 30-year old hybrids has given negative rooting results.

3. T-budding, on several stocks, has not been a successful means of propagation.

4. Whip and bark grafting, on compatible stocks, have been successful methods to date.

5. Cleft grafts have been less successful probably due to the difficulty of getting good fits with large caliber wood.

6. Species of oaks may apparently be arranged in two groups relative to their value as stocks.

(a) One group includes the following species and hybrids belonging to the "white oak" group: burr, live, overcup, post, swamp, white, F_2 (live × overcup), and F_2 (live × swamp white). Eighty-four per cent of all whip and bark grafts made on these species have grown. All successful grafts apparently made strong substantial unions, and the scions made vigorous growth.

(b) The other group includes Chinese, water, black jack, and other "black oak" forms (species). These are not promising as stocks for the Ness Hybrids.

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