SOME FACTORS THAT INFLUENCE THE STORAGE AND SEASONING OF PECAN BUDWOOD

THESIS FOR THE DEGREE OF M. S.

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V. R. Gardner

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Submitted to the Department of Horticulture of the Michigan State College in partial fulfilment of the requirements for the degree of Master of Science.

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Introduction

Of the genera included in the Juglans family, the walnuts (Juglans), because of their comparatively wide geographical distribution, were first to receive the attention of propagators. Thomas Andrew Knight (1799) indicated inferentially that propagation of walnuts asexually was a problem (12): "...the walnut succeeds so ill when grafted, unless by approach, that I can scarcely recommend attempts to propagate them in any other way."

During the late forties interest in the propagation of the hickories (Hicoria) resulted in successful asexual propagation. A slave gardener, it seems, Antoine by name (19), first succeeded in grafting the pecan (Hicoria pecan). In 1846 or 1847 he grafted sixteen trees of the Centennial variety. If there were earlier successful attempts, they seem to be unrecorded.

During the period of fifteen or twenty years following 1885, a few nurserymen, principally of the southeastern states, began the production of trees of named varieties of the pecan. A report in 1901 of experiments conducted by the U. S. Department of Agriculture (1) indicates that the whip or tongue graft, was in use at that time. The cleft graft and flute bud were used prior to, and during that time in the propagation of walnuts, and since have been used also on the hickories. It seems reasonable, then, to presume that pecan trees produced by graftage during the period referred to above may have been propagated by the cleft graft, tongue graft, flute bud, or a slight modification of one of these methods.

In 1912, Van Deman (21) stated that grafting and budding were employed in nut tree propagation, that tongue, or splice, and cleft graft were used, that the patch bud was satisfactory, but that the shield bud could not be used with assurance of success. Since then, the use of the patch bud and its various modifications has undoubtedly become more general. In 1917 J. A. Evans, A. and M. College Extension Service, College Station, Texas demonstrated that patch buds could be successfully inserted in rough thick bark of limbs three or more inches in diameter. That possibility renders it especially valuable for top-working native or undesirable trees.

Stuckey and Kyle (19) indicate that early attempts to use the cleft graft in pecan propagation were not entirely satisfactory: "So the ring-bud was introduced, being first used by E.E. Risien. ...The patch bud, or modified ring bud, has become the most important method of topworking native pecan trees, and is rapidly replacing the whip graft in the propagation of nursery trees."

Though other methods, notably the bark graft, may be used, the patch bud and its various minor modifications constitute the principal means by which the large majority of pecan trees of named varieties are produced at the preent time. Incidentally, the patch bud is no recent contribution to the art of plant craft. Columella (4), about 23 A. D., described three methods of graftage, "...the third kind, whereby the tree receives the buds themselves, with a little bark, into a part of itself from which the bark is taken away....It is not fit for all sorts of trees, but for the most part, such as have a moist, juicy, and strong bark...as the fig." His further description is convincing that he was referring to the patch bud.

In the propagation of the pecan by the patch bud, two different types of budwood are used. Wood of the current season's growth is suitable from mid-summer until the end of the budding season. On account of its immaturity it cannot be used earlier than perhaps July 20 with any assurance of reasonable success in even the most southern localities. These buds are known as "current season" buds.

Previous season wood must, of necessity, be relied upon for spring and early summer budding. There are two principal ways in which such budwood is customarily handled prior to its use. One practice involves the cutting of the budwood directly from the trees as it is needed throughout the budding season. This is known as "fresh" budwood. An objectionable feature of this practice is that, with the beginning of growth in spring, many of the most valuable buds force into growth and either form twigs or abscis, before the budwood can be used. The "basal buds which were forced out as a result of freezing of the terminal and upper lateral buds," referred to by Shuhart( ), were undoubtedly lateral buds of a type used as a source of patch budding material. At any rate, these buds are available for use only during a relatively short period in the early spring. The result is that propagators experience difficulty in obtaining suitable budwood for late spring and early summer work.

Varietal differences are reflected in the usefulness of buds which may be found on trees of a given list of varieties at a given time. In general, the western varieties yield little satisfactory budwood after growth has begun in the spring. The eastern varieties, on the other hand, in general produce from two to five or more buds at each node and, even though the largest and most valuable bud of the group may have advanced too far to be of use, others are present which may be depended upon for satisfactory growth without undue forcing. In addition to the foregoing, climatic variations in the spring influence the number of suitable buds, which may be present on the tree at any given time during the early propagating season.

Another way of handling budwood of previous season's growth involves the cutting of scions from trees during the dormant season and storing them, properly insulated against desiccation, at a temperature of from 32° to 38° F. Budwood handled in this way will be referred to hereafter in this paper as "storage wood." Since it is cut while dormant and, favored by a low temperature, remains in a dormant condition in storage, it must be subjected to conditions that will result in the slipping of the bark, before it can be used as a source of patch buds. This latter process is known as "seasoning", and is accomplished by providing moist insulation and a warm atmosphere.

By seasoning, Woodward (22) says, "We mean taking the budwood from cold storage and keeping it warm and damp until the bark will slip freely." Continuing, he suggests, "the best way to season budwood, after taking it from cold storage, is to cover it with moss or straw. Then wrap a wet burlap sack around it and place it in the shade. However, if the weather is still cold the budwood and burlap sack may be placed in the sunshine provided the sack is kept moist at all times. In case of emergency, when budwood is needed and must be seasoned in a short time, the sticks may be placed directly from cold storage into warm water, which is kept at a constant temperature of 90° F. The sticks must be completely submerged and within a few hours the bark will begin to slip."

Blackmon (2) suggests that sticks for ring and patch budding should be taken out of storage three or four days prior to being used, "as the higher temperature at this later season causes the sap to become sufficiently active to permit the removal of the buds... It is important that the budsticks be kept in moisture holding material after removal from storage until used."

Hutchins (10) mentions "from January to the latter part of February" as the season for cutting pecan budwood from trees, and suggests "a mixture consisting of equal proportions of wet and dry sawdust or shavings" as satisfactory storage or seasoning media. He further states that seasoning is "somewhat of a problem....in early spring before the temperature reaches 75° or 80° F.", and says it takes from "three days to two weeks to bring the wood to a workable condition..."

Burkett (3) recommends "late winter" as the season for cutting budwood, and sawdust, shingle tow, fine shavings, clean sand, sphagnum moss, and newspapers as insulating materials. He advises to"moisten the (packing) material uniformily, but not wet it." According to this writer, a "method of seasoning the budwood is to take a package of it and put in wet moss, sawdust, sand or other good material and lay it out in the sun until the bark slips. A quicker method is to insert the budsticks in a vessel of water with a temperature of from 90° to 100° F. and leave it from two to four hours. With reference to the length of time during which budwood may be used after it is seasoned, he says "remove only enough budwood to be used in a week or ten days."

Thus a variety of materials of unknown comparative merit and various moisture contents are recommended and used for insulation in storage and during seasoning; likewise opinions are at variance as to the most favorable time for cutting budwood. As a consequence perhaps, propagators experience much difficulty and inconvenience in seasoning it. The fact stands, however, that storage budwood is the principal type used prior to July 20 of a budding season.

Objects of This Study

The obvious indefiniteness, if not contradictions, in directions for seasoning budwood, suggesting diversity of experience, seemed to indicate that several factors may affect the process. Accordingly, the investigation reported here was designed:

(1) To determine the relationship between time of cutting budwood of Stuart and Delmas varieties and the length of time required for seasoning;

(2) To compare the responses of budwood of the Stuart and Delmas varieties to conditions considered favorable to seasoning, and

(3) To record the length of time during which storage pecan buds may be expected to remain in viable condition in cold storage after they have been seasoned.

Preliminary Studies

Before these investigations could be undertaken, preliminary studies to determine an optimum temperature and an optimum humidity for the seasoning process were necessary.

At the outset it was thought that perhaps the ideal seasoning temperature would be between 95° and 100° F. Several attempts were made to season lots of budwood in an incubator at these temperatures. Each attempt was more or less unsuccessful; perhaps of a given lot, a limited number of budsticks would become partly seasoned, but entire lots did not season normally. Consequently tests were conducted to determine optimum conditions of temperature.

A given lot of Stuart budwood was divided into three parts. Each part was thoroughly insulated with sphagnum moss of given moisture content, and wrapped in waxed paper. One bundle was held at temperatures ranging from 93° to 98° F., a second at from 78° to 85° F., and the third at from 63° to 68° F. The test was repeated with another lot of budwood of the same variety and substantially the same results were obtained in each test. Budsticks did not season normally at either the high or the low temperature ranges. They did season normally at temperatures from 78° to 85° F., and throughout the investigations reported in this paper this temperature range was found effective in seasoning budwood.

To measure possible differences in results secured by seasoning under various degrees of humidity, a given lot of Stuart budwood was divided into three parts. One of these was seasoned in sphagnum moss to each 100 grams of which 688 grams of water had been added; a second part in sphagnum moss to each 100 grams of which 544 grams of water had been added, while the third was seasoned in moss that contained only 172 grams of water per 100 grams of moss. In each instance waxed paper was used as wrapping material to restrict evaporation and maintain a uniform moisture content. This test was duplicated with the Delmas variety. Somewhat later 24 budsticks were placed for seasoning in moss that contained 1000 grams of moisture to each 100 grams of moss; and a duplicate lot of 24 budsticks was placed in moss that contained only 150 grams of water to each 100 grams of moss. In all these tests, budwood seasoned in the same length of time regardless of the relative moisture of the moss. The deduction seems reasonable that the role of moisture is only to prevent desiccation.

Of incidental interest in this connection is the fact that budsticks seem not to change in weight to any marked extent during the seasoning process. In two tests in which a total of 64 budsticks were weighed carefully before and after seasoning the differences in the weights were in all cases so small as to come within the range of experimental error.

In connection with results obtained with insulating materials of various moisture contents, the statement of Shippy (20) with respect to the callusing of apple cuttings is possibly pertinent, though it refers to a different process. He says: "Considerable moisture tolerance is indicated by the fact that callus formed almost equally well in media varying in water content from 97 to 437 per-cent. Further these results indicate that once the moisture content of the medium is saturated, additional quantities of water have little or no stimulating effect on callus formation..." He indicated further "the desirability of actually having liquid moisture in contact with the cuttings", rather than merely to expose the cuttings to a saturated atmosphere... The liquid moisture perhaps need be no more than a film, for good callusing has been had repeatedly in a medium only slightly moist to the touch; in fact a medium in which cuttings have actually decreased in weight due to water loss."

Relationship Between Time of Cutting Budwood and the Length of Time Required for Seasoning.

Since the seasoning process results in changes similar to, if not identical with, those characterizing resumption of growth in early spring, the period required for seasoning budwood cut at various times during the winter may conceivably be governed by rest period phenomena. That this is so cannot be assumed a priori, however, since seasoning affects primarily the cambium region, while rest period phenomena have been observed primarily in buds. On the other hand, the small amount of definite study of cambium behavior in rest period investigations leaves the possibility that this behavior follows the phenomena exhibited by buds.

Jost (11) cited R Hartig as showing that callus formation and root development in cuttings, both products of cambium activity, occur during the rest period. In addition Jost reported experiments of his own leading to the same general conclusions.

Simon (18) observed that callus forms from the cambium on cut surfaces of cuttings, as a wound reaction, even during the winter rest, but that it was produced more readily and ultimately in greater quantities from cuttings that were not in the resting condition. He concluded that the rest period no longer appeared as a time of complete inactivity, but simply as one during which only certain growth functions in consequence of the constellation of inner conditions were brought to a standstill; and that respiration and certain other physiological functions, so far as not inhibited by outer conditions, continue their course.

In America, Curtis (5) reporting on the behavior of Ligustrum ovalifolium cuttings, treated with potassium permanganate solutions, considered that the treatments did not break the rest period of the whole cutting, since bud development was alike on treated and untreated cuttings. He considered it possible, however, that disturbances localized at the bases may have served to start growth in the dormant cambium, since roots formed more freely on the treated material.

Perhaps it is because most rest period investigation has been done in Europe, where the pecan is very rare, that no information is available as to its rest period behavior, except a statement by Howard (8) that species of Hicoria are refractory toward ending the rest.

Between the fifteenth and twentieth of each of the months of December, January, February, and March of each of the winters of 1928-29, 1929-30, and 1930-31, budwood was taken from pecan trees in the orchard of the Department of Horticulture of the A. and M. College of Texas. The trees had been planted in the orchard in 1920 and 1921, and consequently had reached bearing age prior to the beginning of this test. Individual budsticks obtained from these trees were approximately one-half inch in diameter at the base, from 1[illegible] to 1[illegible] inches long and had been formed during the previous growing season. In general, budsticks used in this test were of a type considered ideal for the purpose of patch budding.

On the date on which each lot of budwood was cut, it was packed in sphagnum moss, to each 100 grams of which 688 grams of water had been added in a way that ensured uniform distribution throughout the moss. Apple boxes were used as storage containers. Packed in such boxes, the budwood was stored in the college ice house. The storage temperature ranged from 38° F. in the early part of the period to 32° F. during the latter part.

With the approach of the season for patch budding each spring, samples of budwood of each of the two varieties cut during each of the months of December, January, February, and March were taken and held for seasoning. Uniform conditions of moisture and temperature were provided by packing all the budsticks to be used in a test, in a single container. Sphagnum moss, moistened with 688 grams of water to each 100 grams of moss, was used as insulating medium during seasoning. Waxed paper was employed to restrict evaporation of moisture, though no attempt was made to make the package air-tight. When packed, the boxes were placed in a steam heated room, the temperature of which could be maintained rather accurately at from 80° to 85° F.

Budwood was inspected at intervals and the date on which a considerable number of budsticks of a given lot were found to be seasoned was recorded as the "date of inspection".

Results of all tests conducted with the purpose of determining the relationship between time of cutting pecan budwood of the Stuart variety and the length of time required for seasoning are summarized in Table I. Inspection of results of any one lot included in that table indicates that seasoning of budsticks cut relatively late in the dormant period, takes place in a shorter period than is required for those cut early. Of 50 budsticks cut in December, only 10 were seasoned on date of inspection; 12 of 50 cut in January, 32 of 50 cut in February and 40 of 40 cut in March were seasoned on date of inspection.

The quicker response of budwood cut late in the season seems to indicate the existence of a rest period in the pecan and that the influences governing the end of the rest period are operative in wood remaining on the tree and not fully operative in wood held at temperatures slightly above freezing.

Differences in the response of Delmas budwood to seasoning conditions are less pronounced than those recorded for Stuart. The totals given in Table II. shows that of 50 budsticks cut in December, 30 were seasoned on date of inspection; 45 of 50 cut in January, and all that were cut in February and March were seasoned on date of inspec-

Table I

Relationship between Time of Cutting Budwood of Stuart Pecan and Length of Time Required for Seasoning (in 1929, 1930, and 1931).

No. in test	Date seasoning began	Date inspection	Cut in December		Cut in January		Cut in February		Cut in March	
			No.	No. seasoned	No.	No. seasoned	No.	No. seasoned	No.	No. seasoned
	1929									
6	5/20	5/25	2	0	2	0	2	1		
6	5/20	5/27	2	0	2	0	2	1		
	1930									
16	5/1	5/3	4	1	4	4	4	4	4	4
16	5/7	5/9	4	1	4	2	4	2	4	4
16	5/16	5/17	4	1	4	1	4	0	4	4
	1931									
18	2/18	3/3	6	1	6	0	6	3		
40	3/18	3/23	10	1	10	0	10	4	10	10
72	5/4	5/6	18	5	18	5	18	17	18	18
	Totals		50	10	50	12	50	32	40	40

Table II

Relationship between Time of Cutting Pecan Budwood of Delmas Variety and Length of Time Required for Seasoning in (1929, 1930, and 1931).

No. in test	Date seasoning began	Date inspection	Cut in December No.	Cut in December No. seasoned	Cut in January No.	Cut in January No. seasoned	Cut in February No.	Cut in February No. seasoned	Cut in March No.	Cut in March No. seasoned
	1929									
6	5/20	5/25	2	1	2	1	2	2		
6	5/20	5/27	2	0	2	2	2	2		
	1930									
16	5/1	5/3	4	4	4	4	4	4	4	4
16	5/7	5/9	4	4	4	4	4	4	4	4
16	5/16	5/17	4	3	4	4	4	4	4	4
	1931									
18	2/18	3/3	6	5	6	5	6	6		
40	3/18	3/23	10	0	10	8	10	10		
72	5/4	5/6	18	13	18	17	18	18		
Totals			50	30	50	45	50	50	12	12

tion. In view of the fact that Delmas responded more readily to conditions of seasoning throughout this test, as will be discussed later, it is probable that if inspection had been made a day or two earlier for each lot, differences in response of Delmas wood cut early and late would have been more pronounced.

Reference to Table III., which presents a part of the data shown in Tables I and II, shows that the periods required for seasoning budwood become progressively shorter as the season advances, regardless of the time at which it was cut. Howard (8) states that: "The rest period of plants does not end suddenly. On the contrary, under natural conditions it ends very slowly."

Chandler's (6) statement that "Growth response is more rapid the more nearly the plant is out of rest" is a suggestion of an explanation of this observation.

Neither Stuart nor Delmas, cut directly from trees, seasoned in the period from December 15 to January 5; scions were dead on the latter date. Stuart and Delmas cut in December and held in cold storage until January, and Delmas cut directly from trees, seasoned in the period of 19 days following January 18; Stuart cut fresh from trees on January 18 did not season in the same period.

Delmas budwood cut in December, required 15 days for seasoning in February, and only two days in May. Of Delmas cut in January, five out of six sticks seasoned in the 15 days following February 18; in the test con-

Table III

The Number of Days Required for Seasoning on Successive Dates during the Budding Season, in 1931.

Date cut	Seasoning begun 60 days after December 18, 2/18/31				Seasoning begun 90 days after December 18, 3/18/31				Seasoning begun 136 days after December 18, 5/1/31.			
	Days in storage	Days required	No.	Seasoned	Days in storage	Days required	No.	Seasoned	Days in storage	Days required	No.	Seasoned
Stuart												
12/18	60	15	6	1	90	5	10	1	136	2	18	5
1/18	30	15	6	0	60	5	10	0	106	2	18	[illegible]
2/18	0	15	6	3	30	5	10	4	76	2	18	[illegible]
3/18	-	-	-	-	0	5	10	10	46	2	18	1[illegible]
Delmas												
12/18	60	15	6	5	90	5	10	0	136	2	18	1[illegible]
1/18	30	15	6	5	60	5	10	8	106	2	18	17
2/18	0	15	6	6	30	5	10	10	76	2	18	1[illegible]

ducted a month later 8 of 10 budsticks seasoned in five days; and six weeks later still scions from the same lot seasoned in two days out of storage (May 4-6). Of Delmas cut in February, all budsticks seasoned in 15 days in February, 5 days in March, and 2 days in May.

Data for Stuart do not suggest the rest period phenomenon so clearly, perhaps because Stuart does not season normally in as short a time as Delmas and consequently progress of Delmas in seasoning determined in a large measure when the data was taken. Only three out of six Stuart scions, cut in February, seasoned in February in 15 days. In March four of 10 scions cut on the same date, seasoned in five days; and May, 17 out of 18 scions seasoned in two days. Of Stuart scions, cut in March, all seasoned in five days in March and in two days in May. It will be recalled that the scions that composed each lot were held in cold storage from the various times they were cut until the seasoning process was begun for respective lots. The seasoning temperature for each lot ranged from 80° to 85° F. These results are in accord with the views of the writers cited above regarding the tissue concerned in the rest. In them are found indications that the same or a similar influence - whatever it may be - which prevents or inhibits twig growth likewise prevents or inhibits cambial activity; and cambial activity is involved in the seasoning process.

Though the difference in budwood cut early and that cut late (Table I) indicates that storage at temperatures slightly above freezing delays the breaking of the rest period, the fact that wood cut on a given date seasons more rapidly as the budding season advances, indicates that the storage conditions do not completely suspend the ending of the rest period. These two rather contradictory manifestations suggest that the breaking of the rest period depends on more than one factor, one (or more) being affected, and one (or more) being unaffected, by low temperatures.

It is worth recording that pecan bark slips prior to the time when the buds burst. In the spring of 1931, a half-dozen Stuart trees were examined. Lateral buds in terminal positions on twigs of the 1930 season had become greatly enlarged, and were showing tinges of green color, indicative of growth, but none had burst the bud scales surrounding it. Bark on parts of the trees representing each year's growth from 1924 to 1930 slipped readily. Budwood likewise may be seasoned perfectly before any of the buds burst their scales. Whether or not the rest period, as popularly conceived, has been completely broken prior to the growth of buds in these cases, cannot be stated definitely without experimental treatment, but the manifestations are identical in naturally and in artificially seasoned budwood. It frequently happens that patch buds, inserted throughout th budding season, unite with the stock, but the buds of the patch remain dormant for a considerable period. The primary bud, of the group of two, three, four or more buds found at a node, may either grow into a twig or limb, abscise or remain dormant, though this last case is somewhat unusual. It is not unusual, however, for the other buds at the node to remain dormant for two, three, and four years. It is of course, thoroughly possible, and quite probable, that continued dormancy in these cases is prescribed by conditions of nutrition and that the rest period is not involved - if we assume for the time that there is no relationship between the two.

Consistent with Howard's (8) suggestion that species of Hicoria are the most refractory species with reference to breaking the rest period, it has been observed that breaking of the premature rest period of pecan trees, brought on by severe drought, by late summer or fall rains is unusual. From casual observation covering a period of ten years, the writer recalls only one year in which "second growth" has occurred in fall after dormancy was established. Leaves formed during this second growth persisted green until after Christmas, whereas they usually fall by November 1 or 15 regardless of weather conditions.

Comparison Between Stuart and Delmas.

Comparison of Tables I. and II. shows a marked difference in the response of the two varieties to seasoning condition. Of a total of 50 budsticks of each variety cut in December, 30 Delmas were seasoned on date of inspection as compared with 10 of Stuart; 45 Delmas cut in January as compared with 12 Stuart of the same month; all 50 Delmas budsticks and only 20 of 50 Stuart cut in February were seasoned on date of inspection. Results summarized in Table IV emphasize these differences. It is evident that Delmas is more sensitive than Stuart in its reaction to moisture, temperature and the other factors, whatever they are, that tend to initiate seasoning.

This seems peculiarly interesting since normally the growth of Delmas trees is prolonged later in fall than that of Stuart. In normal years the harvest period for Delmas nuts is from November 1 to 10 in the vicinity of College Station, Texas; Stuart nuts in contrast are ready for harvest from the fifth to fifteenth of October. An objectionable feature of the Delmas variety is that it ripens its fruit so late in the season that the crop is sometimes ruined by early frosts. Yet Delmas budwood cut in December and January is more responsive in seasoning than budwood of Stuart.

Interesting, and perhaps significant also in this consideration, is the fact that Delmas trees initiate

Table IV

Comparison of Responses of Stuart and Delmas Pecan Budwood to Conditions Considered Favorable to Seasoning.

Date cut	Date Seasoning Began	Date of Inspection	No. Stuart Budsticks in Test	No. Stuart Budsticks Seasoned on Inspection	No. Delmas Budsticks in Test	No. Delmas Budsticks Seasoned on Date of Inspection.
12/14/28	5/20/29	5/25/29	2	0	2	1
1/14/29	"	"	2	0	2	1
2/21/29	"	"	2	1	2	2
12/14/28	"	5/27/29	2	0	2	0
1/14/29	"	"	2	0	2	2
2/21/29	"	"	2	1	2	2
"	"	5/25/29	2	1	2	2
"	"	"	2	2	2	2
"	"	"	2	2	2	2
"	"	"	2	1	2	2
"	"	"	2	0	2	2
2/14/30	2/14/30	2/24/30	3	0	3	3
12/20/29	5/1/30	5/3/30	4	1	4	4
1/20/30	"	"	4	4	4	4
2/20/30	"	"	4	4	4	4
3/10/30	"	"	4	4	4	4
12/20/29	5/7/30	5/9/30	4	1	4	4
1/20/30	"	"	4	2	4	4
2/20/30	"	"	4	2	4	4
3/10/30	"	"	4	4	4	4
12/20/29	5/16/30	5/17/30	4	1	4	3
1/20/30	"	"	4	1	4	4
2/20/30	"	"	4	0	4	4
3/10/30	"	"	4	4	4	4
12/18/30	2/18/31	3/3/31	6	1	6	5
1/18/31	"	"	6	0	6	5
2/18/31	"	"	6	3	6	6
12/18/31	3/18/31	3/23/31	10	1	10	1
1/18/31	"	"	10	0	10	8
2/18/31	"	"	10	4	10	10
12/18/30	5/4/31	5/6/31	18	5	18	13
1/18/31	"	"	18	5	18	17
2/18/31	"	"	18	17	18	18
Totals			175	74	175	151

growth earlier in the spring than Stuart. Ordinarily by the tenth of March, Delmas trees are showing signs of growth. Bark of budwood material slips readily at that time and the wood is undesirable for storage purposes. It was on this account that Delmas budwood was not stored in March in 1929 and 1931. Stuart budwood, on the other hand was found to be in an apparently dormant condition each year until after March 12.

Cross-sections representing dormant and seasoned Stuart and Delmas budwood at differents periods from December to May show no differences between the two varieties in the appearance of the cambium region.

The potassium iodide test for starch was used in an effort to determine possible differences between starch content of Delmas and Stuart. So far as could be determined by the test employed, there were no consistent differences between either seasoned or dormant wood of the two varieties.

Since Delmas manifestly prolongs its autumnal activity later, and begins spring activity earlier, than Stuart, it is difficult to conceive of earlier advent of the rest period as explaining the earlier spring growth and the inference seems inevitable that has a shorter or less intense rest period than Stuart.

Cambium Activity

In some studies of growth renewal, as e.g., that by Hastings, (9) slipping of the bark has been used as an index of cambial activity. Knudson (13) has shown that with the peach "cambial activity began ... at the time of the opening of the buds", and Hastings (9) and Nobel (14) regard slipping of bark as an index to cambial activity. Since seasoned budwood is wood on which the bark slips freely, and since seasoned budwood quickly becomes overseasoned, i. e., useless for budding, while the bark still slips freely, knowledge of the changes occurring in this period seem desirable.

In this work studies were made of transverse sections representing (1) wood taken directly from the dormant trees, (2) wood removed from cold storage, (3) wood during various stages of the seasoning process, and (4) overseasoned wood. Sections were cut, 20 to 30 microns thick, from fresh material on a sliding microtome. This procedure was adequate for examination of the woody cylinder, but not entirely satisfactory for examination of the bark, particularly in material in which the seasoning process was well advanced.

The sections were cut into 50 percent alcohol, stained overnight in safranin, destained in acid alcohol, carried through alcohol series into xylol, stained with a xylene solution of gentian violet in clove oil, and mounted in balsam.

Sections made from dormant budwood (see Plate I) show a cambium region of from three to six cells in radial thickness, at different points within a section. In total thickness this tissue ranged from 29 to 75 microns. In a majority of the cases studied, the cambium region was three and four cells thick radially, with corresponding total thickness of from 36 to 46 microns. It was somewhat difficult to distinguish the outer cells of the cambium from those that were perhaps last-formed phloem cells. In many instances there was a gradation in size and shape from the thin-walled, rectangular cells adjacent the xylem to larger thicker-walled cells that were assuming more nearly a square outline. Seventy-seven observations each on sections of dormant and of seasoned wood were recorded. Counts were made alternately on dormant and on seasoned sections in order to minimize differences that might result from changing standards. Data obtained are recorded in Table V. No significant differences between seasoned and dormant wood in these two respects were evident. (Compare Plates I and II).

Apparently then, the bark slips before cell division occurs in the cambium region. Support is given this view by unpublished observations of Prof. F. C. Bradford, Michigan State College, East Lansing, Mich., on peach and apple.

Table V

Radial Thickness of Cambium Region of Dormant and Seasoned Budwood.

Dormant				Seasoned			
Class Microns	M	N	M x N	Class Microns	M	N	M x N
28-37	32.5	25	812.5	28-37	32.5	16	520
38-47	42.5	26	1105	38-47	42.5	38	1615
48-57	52.5	22	1155	48-57	52.5	19	997.5
58-67	62.5	2	125	58-67	62.5	3	187.5
68-77	72.5	2	145	68-77	72.5	1	72.5
		77	3342.5			77	3392.5

Mean = 42.1 Mean = 42.7

Number of Cells in Thickness of Cambial Region in Dormant and Seasoned Budwood.

Class Range	M	N	M x N	Class Range	M	N	M x N
3	3	23	66	3	3	19	57
4	4	46	182	4	4	51	204
5	5	5	25	5	5	6	30
6	6	3	18	6	6	1	6
		77	291			77	297

Mean = 3.779 Mean = 3.857

Several lots of budsticks were allowed to continue the seasoning process beyond the stage at which they were suitable for use for patch budding, i. e. until over-seasoned. It is seldom that buds on normally-seasoned wood show signs of beginning growth, and advancing buds characterize over-seasoned wood. One lot of budwood was removed from storage on April 22, and was seasoned four days later. Sections of basal and terminal portions of sticks of this lot were cut 12, 23, and 28 days following removal from storage, that is, eight, 19 and 24 days after seasoning had occurred.

Since each series of sections was cut from a portion of the stick immediately beneath a bud, the lower leaf trace appears prominently and the two lateral distinctly visible (Plate III) in each section. Two sets of traces may be recognized in sections that were evidently taken from portions of budsticks on which the internodes were short. Both terminal and basal sections (Plates IV and V) of this lot show that new vessel formation and lignification had taken place prior to the twelfth day, and their number had markedly increased in 28 days. By counting the number of vessels seen in several low-power fields of the microscope, an approximation of the relative numbers of vessels in terminal and basal sections on successive dates was derived. Summarized results follow:

Days of Seasoning	Relative Frequency of Vessels	
	Basal	Terminal
12	5	1
23	10	15
28	14	23

Vessel lignification, it seems is simultaneous with, or very soon following, the bursting of buds. In the examination of broad-leaved trees, Hastings (9) found that, "no increase in thickness took place until buds had opened and the first leaves expanded... The first growth was not continuous around the stem, but of vessels and tracheids in irregular groups." The table above suggests that cambial activity and the subsequent vessel lignification in the base of pecan budsticks precedes the same process in the terminal (support is given this view by observations on disbudded wood discussed later); once initiated, however, these processes proceed with greater activity in the terminal than in the base. It should be noted, however, that, in general, buds on terminal parts of budsticks advance in growth more rapidly than those on the basal. Priestly and Swingle (16) regard a section of the axis with its attendant leaf as a "natural growth unit, made up of a leaf and a portion of the axis below, down to the insertion of the next leaf vertically beneath." It seems that this statement may account for the greater rate of development of vessels in the terminal portions.

In sections which clearly contained only one set of leaf traces (Plate VI), vessels were more numerous in the half of the section which contained the traces. In sections which showed signs of two sets of traces, an association of the distribution of vessels with traces was evident. A series of sections which clearly revealed only on set of traces showed an average of 24 vessels in the half of the section in which the traces occurred as compared with 6 vessels for the other half. This difference was much less pronounced in sections that showed evidences of two sets of traces. In these the distribution of vessels in the circumference of the cambium region was more uniform, an average of one series being 26 vessels in half that contained the larger trace as compared with 20 for the other half, and in another it was 18 as compared with 16.

These observations are in general accord with the findings of Jost (11) and the statement of Priestly and Swingle (16), commenting on the work of Swarbrick and of Grossenbacher, to the effect that ... "upon the tree in the spring, cambial activity begins beneath each bud and works thence downward along the stem." It has already been mentioned that they regarded new growth as starting below the bud. In the pecan material examined in this study, however, new vessels were more numerous in locations lateral to points vertically beneath the bud. One of the three leaf traces is immediately beneath the bud; the other two are somewhat higher, though below the level of, and lateral to, the buds of a node. The question may be raised here then, as to whether the development of new vessels is an association with the bud, or the leaf trace. This however, cannot be settled definitely until the anastomosings of the tissues in the vicinity of the node are worked out.

In the comparatively limited number of sections examined (about 60, representing 10 series), it was extremely rare that a vessel was found in the part of the cambium between the half-dozen xylem rays which extend radially from the end of the most prominent leaf trace. This was true even of budsticks which had seasoned for 28 days. How far beneath the trace this condition prevailed was not determined. Sections cut on May 20 immediately below a bud of budsticks cut directly from trees whose lateral shoots had made from 10 to 18 inches of growth, showed vessels in the region referred to above, but they were not as large or as numerous as those in other parts of the section.

In this entire study it has seemed that the slipping of bark is simultaneous in all parts of a budstick. If time of development and lignification of vessels be accepted as an index to the beginning of cambial activity, however, it is clear that the process begins first in the base, but is followed very soon by activity in other regions. It will be shown later, however, that the seasoning process may be initiated without subsequent vessel lignification, even in over seasoned wood.

It will be remembered that the over-seasoned lots were packed in horizontal positions in moist sphagnum moss and were kept in total darkness. Lignified vessels began to appear prior to the twelfth day. By the twenty-eighth day, the vessels were apparently about normal in size for the species, and as numerous as those found in sections from fresh wood cut directly from the trees. (Pl. XIV) In the meantime practically every trace of starch had disappeared from the tissues which formerly were loaded with it, and buds had made from an inch to an inch and a half of growth. These young shoots were entirely devoid of green color. It seems evident then that the new vessels were built up from reserve foods without the aid of photosynthesis in the current season.

Briefly, then, sections of overseasoned wood showed differentiated and lignified vessels interspersed between elements that were as yet incompletely differentiated. When the bark slips the line of splitting (Plate VII) seems to be at the line where new growth began (the annual ring) instead of at the cambium. The suggestion is presented that the adhesion of partly differentiated elements to the bark may serve as a buffer between the meristems of the patch bud and that of the stock on which it is placed, and thus interfere with the union. It is perhaps significant that the surface of the stock must often be in the same condition when it receives the bud; regeneration however, must occur more freely on the stock. It seems plausible that death of patches in such cases is due to the (1) lack of a functional meristem, and, as has already been mentioned, (2) scarcity of reserve food in the form of starch. (This last is significant in view of Mer's (15) suggestion that cambial activity is initiated first in the best nourished portions of a plant).

Disbudding Studies

R. Hartig, as cited by Jost (11), stated that in some trees diameter growth begins before the leaves unfold; in addition he removed all buds from a young beech and still found new wood formed. Jost himself allowed potted trees of horse chestnut, oak and red beech to grow in complete darkness; these trees also formed new wood, but Jost regarded the unfolding of buds to be normally antecedent to the formation of new wood.

A lot of 18 dormant budsticks, directly out of storage, was divided into three parts of six sticks each. The sticks of one part were completely disbudded; the terminal halves of a second part, and the basal halves of the third were likewise disbudded. With these preliminary treatments, they were placed in sphagnum moss for seasoning. Examination on the sixth day showed that all parts of the budsticks, irrespective of treatments, were seasoned.

After nine and sixteen days, transverse sections were cut from terminal and basal portions of budsticks that represented each of the treatments mentioned above. The sections representing the two were practically identical in what they showed with respect to development and lignification of vessels. Of the sections from disbudded sticks, (Plates VIII - XII) none showed vessels; of those from terminally disbudded sticks, basal sections showed vessels, while terminal sections did not; and of those from sticks, basal parts of which had been disbudded, basal sections showed vessels on the ninth day and terminals did not, while by the sixteenth day both basal and terminal sections showed vessels.

Counts of the number of vessels in each of from three to ten terminal and basal sections, selected at random and representing the treatments named previously, were made. The range in number of vessels in the half of the section in which the most prominent trace occurred is as follows:

Treatment	Range in No. of Vessels in Sections of a Series.	
	Basal Sections	Terminal Sections
1. Completely disbudded	0	0
2. Disbudded terminal half.	7 to 13	0
3. Disbudded basal half.	18 to 36	9 to 60

In other words, expanding buds, even though they are exposed to light, seem essential to vessel development. Expanding buds in terminal positions exert an influence which results in vessel formation in a disbudded basal portion, prior to their formation in the terminal, but buds growing on basal portions do not exert a similar influence on disbudded terminal parts.

The Quinhydrone method of determining the respective P_H values of dormant and seasoned wood was employed. Bark was peeled from wood in narrow strips, the inner surface scraped and 0.1 gm. of the material macerated in 30 C.C. of distilled water, the P_H value of which had been determined as 6.8. Two tests were made on each budstick and in most cases they checked within 0.3. Of the three dormant budsticks tested, the P_H values were 6.2, 6.2, and 5.6 respectively. Similar values for seasoned budwood ranged from 6.4 to 6.8 for seven budsticks. Quantities of pecan budwood of the two classes that would justify conclusions that could be considered trustworthy were not available. In the absence of additional pecan material tests were made on seasoned and dormant walnut scions. They were not uniform, however, and P_H values showed no consistent differences between the two.

Starch Transformation

One of the most obvious changes accompanying resumption of growth activity in spring is the so-called "starch migration", the transformation of starch to sugar and the reverse, so that it disappears at one point and appears at another. Since the processes are rather easily followed, at least in a rather crude manner, by the iodine tests, they were used as a means of comparing growth-resumption phenomena in seasoned and in normal budwood. It is, of course, to be recognized that storage as oil or fat may be an important factor in the pecan.

"Starch migration" has been reported in some detail by several investigators.

Mer (15) in tracing the migration of starch in the oak, beech, maple and other species found that it traveled toward growing shoots through the annular pith and the most internal layer of the starch sheath, and that starch was depleted first in internodes nearest the most vigorous growing shoots, which in most cases was near the terminal. Working with twigs, - on the tree, and detached, - which had been partially disbudded, he concluded that starch accumulated always in the proximity of the remaining bud, leaf, or growing shoot.

Reichardt (17), working with willow, poplar, beech, oak, linden, and other species, found that starch was deposited in the pith sheath, xylem and phloem parenchyma, xylem rays, and wood fibers. His observations were on one-year-old twigs, some of which were taken directly from the tree while others were handled as cuttings. Solution of starch took place only after growth began. Its disappearance was first from the internode. Disbudded portions behaved like internodes. Starch disappeared first from wood parenchyma, then from wood fibers, pith sheath, and from within outward in the medullary ray. Transitory starch first appeared in the bark, then in starch-containing cells in the vicinity of nodes provided with buds.

No reports are available on starch transformation in the pecan.

Transverse sections were made from internodes of wood suitable for budwood. They were cut between 15 and 30 microns in thickness, treated with a five percent solution of iodine in potassium iodide for a minute and a half, and examined immediately under the microscope. The first tests were made in December and others made on various lots until June 1. Repeated tests were made on dormant budwood throughout the storage period.

In general, clusters of starch grains appeared in abundance in the periphery of the pith, in medullary rays from pith to cambium and in xylem parenchyma. If starch was present in cells outside the cambium, its presence seems to have been obscured.

Considerable variation was found in the amount of starch indicated and in the frequency of its occurrence in cells of the various tissues. It was not at all uncommon for sections from two sticks of a given lot to present differences in tissues in which starch was deposited; perhaps one would show an abundance in the xylem parenchyma, another only a trace, or none at all. Reichardt (17) noted the same inconsistency in the solution of starch from twigs. He said "... with equally advanced development of the young branch and leaves the solution of the starch did not maintain uniform relation, but ... preceded in one and lagged behind in another..."

No differences in amount of starch present, or in its occurrence in the various tissues could be detected between sections from dormant wood, regardless of when it was cut or how long it had been in cold storage. No consistent differences could be detected between either basal or terminal sections of any of the following: (1) dormant budwood from storage, (2) dormant budwood cut from trees, (3) normally-seasoned wood from storage, (4) fresh budwood cut just prior to the beginning of growth in spring, (5) fresh wood cut when current growth was six inches long and catkins were nearly mature and (6) seasoned budwood which had been returned to cold storage and held three weeks.

These observations, in so far as they apply to dormant budwood and seasoned budwood prior to growth of buds, are in accord with the conclusion of Reichardt (17) to the effect that, "The solution of starch occurs only after growth has begun... Before the buds had swollen or broken out, solution of starch was not observed."

Sections from budsticks which had seasoned 18 days and consequently were over-seasoned showed practically no starch in the pith and only occasional grains in the rays and xylem parenchyma. The buds of this lot had grown out an inch or an inch and a half, but no chlorophyll had developed. This, too, is in accord with Reichardt's observation that "after young leaves have developed a decrease of starch is to be perceived in the whole internode," and "in the twigs which grew in the dark, after a month all starch was exhausted." Jost (11) records depletion in trees grown in complete darkness, which he attributed to consumption by the new growth. Perhaps in the pecan wood the starch may have been consumed in diameter increase, though of course it may simply have been transformed to another substance.

It is interesting to compare these observations with those made in connection with an examination of sections from budwood cut directly from the trees when new growth was six inches long and vessels had apparently reached about the same state of development and lignification as those of the overseasoned budwood. These sections showed the unusual distribution of starch in pith, xylem rays, and wood parenchyma. On the other hand, sections made from fresh wood cut after trees had made terminal growth of from 10 to 18 inches and in many cases had set fruit, and several layers of new xylem had been laid down, showed no trace of starch in any of the starch-containing tissues.

Starch tests were made on budsticks that had been given the various disbudding treatments discussed previously. No differences in the amount or location of starch in sections that represented the various treatments could be detected at the end of sixteen days. It will be recalled that practically all starch disappeared from over-seasoned wood in twenty-eight days.

In short then, the pecan appears to follow the course of starch transformation common to most deciduous trees, and the behavior of seasoned budwood in this respect seems identical with that of normal budwood. The absence of pronounced starch changes may be tentatively assumed as indicating absence of pronounced changes in fats, since in most woody plants there seems to be a rough reciprocal relationship (7) between the two during the winter months.

Longevity of Seasoned Budwood

Partly by accident the writer was prompted to initiate this phase of the study. Seasoned budwood of the Stuart variety was as a matter of convenience put back in cold storage on May 4, 1929. Later examination indicated that the bark was still slipping and the budwood was in good condition for use. At the end of nine, 16, 23, and 37 days buds were taken from this lot and inserted on nursery stock. Of a total of 16 buds, one failure was recorded and the identity of two others was lost. But it was significant that three out of four buds inserted at the end of a storage period of 37 days, grew.

In 1930 and 1931 more comprehensive tests were conducted. In each year budwood was cut about the middle of February and held in cold storage until the early part of April. At that time entire lots were removed from storage, allowed to season and were returned to cold storage at temperatures ranging from 32° to 38° F. They were then in ideal condition for patch budding and could be used directly out of storage without preliminary treatment. Samples of budwood of different varieties included were taken out, as far as practicable at weekly intervals and inserted in uniform nursery trees.

Results of these tests, tabulated in Table VI, show that it is possible to hold seasoned budwood of the varietics indicated in cold storage for at least a period of three or four weeks without a significant decrease in the number of buds that will grow when used for propagation purposes. In 1931 a good percentage of buds grew after 32 days in storage. Incidentally the buds made no apparent growth in storage. Cambial activity stimulated during the seasoning process did not proceed in storage, though the bark continued to slip during the entire storage period. Cross-sections from lots of seasoned budwood that had been held in cold storage for 28 days show a cambium region indistinguishable from that of normally-seasoned budwood, and no decrease in amount of starch in any of the tissues was apparent at that time. On the contrary, as has already been reported in sections from over-seasoned budwood, at the end of 28 days, vessels had formed, buds had grown out an inch or more, and starch had disappeared from all the tissues.

The practical utility of holding seasoned buds in storage appears especially significant when it is remembered that nurserymen and propagators in general experience difficulty in getting budwood to season at the proper time. This difficulty may be due to cool weather or lack of consistency in the response of budwood to seasoning conditions. Propagators who use storage buds occasionally have to suspend work, perhaps during a critical period, on account of a lack of properly seasoned budwood; likewise it happens that budwood is lost on account of rain or other unfavorable weather conditions that may delay its use. It is more convenient to have budwood seasoned and ready for use than to anticipate a need for it three or four days or a week ahead of time. Further, nurserymen who follow a practice of selling budwood, would it seems, have a greater demand for wood that could be used on delivery than for wood that would require a period of seasoning.

Incidentally, some preliminary work in storing fresh budwood indicates that wood of that kind can be held practically as long as seasoned wood; here, however, the utility involved is not so much the matter of convenience, as the probability of getting better buds at the time they would be stored than would be available later in the season.

Table VI

The Longevity of Storage Budwood in Cold Storage After Seasoning.

Variety	Date Seasoned	Date Buds Set	No. of Days in Storage	No. of Buds Set	No. Dead	No. Living
Stuart	5/4/29	5/13/29	9	4	Records lost(2)	2
"	"	5/20/29	16	4	0	4
"	"	5/27/29	23	4	0	4
"	"	6/10/29	37	4	1	3
Tex.Pro.	4/12/30	4/16/30	4	15	1	14
Burkett	"	"	4	10	1	9
Schley	"	"	4	10	2	8
Delmas	"	"	4	10	1	9
Tex.Pro.	"	4/23/30	11	12	2	10
Burkett	"	"	11	12	2	10
Schley	"	"	11	15	2	13
Delmas	"	"	11	15	1	14
Tex.Pro.	"	4/30/30	18	10	1	9
Burkett	"	"	18	10	1	9
Schley	"	"	18	12	1	11
Delmas	"	"	18	10	3	7
Tex.Pro.	"	5/7/30	25	10	3	7
Burkett	"	"	25	10	4	6
Schley	"	"	25	10	1	9
Delmas	"	"	25	10	0	10
Burkett	4/23/31	4/27/31	4	40	29	21
"	"	5/4/31	11	40	10	30
"	"	5/11/31	18	40	9	31
"	"	5/18/31	25	40	20	20
"	"	5/25/31	32	40	21	19
Stuart	4/22/31	4/23/31	1	40	16	24
"	"	4/30/31	8	40	13	27
"	"	5/11/31	19	40	13	27
"	"	5/21/31	26	40	14	26

Discussion

On the practical side this study has established: (1) that budwood seasons better at some temperatures than at others, higher and lower, (2) that beyond a certain minimum, the moisture is not an important factor and that (3) by seasoning budwood and returning it to cold storage the propagator may be assured of a constant supply throughout the season.

Basically the seasoning process is a method of prolonging dormancy and bringing the budwood out of dormancy as required, thereby preventing it from becoming overseasoned before it is used. In the pecan it involves rest period phenomena, as shown by the readier seasoning as the season advances, whether the wood is held in storage or cut fresh from the trees. Most rest period studies have been concerned with buds, with diameter increase or with reactions of cambium near wounds. The present studies show that cambium activity, as measured by slipping of the bark, before cell division begins, follows a course predictable on a rest period basis, independent of wound reactions. It indicates that some of the factors concerned with emergence from the rest period proceed at temperatures slightly above freezing, while others are retarded. In general, however, judged by the standards employed, budwood seasoned artificially seems not to differ from that seasoned naturally.

Observations may be recorded to the effect that new wood is laid down without any photosynthetic activity during the current season and that slipping of the bark is not necessarily a result of cell division. Furthermore, when cell division begins, slipping of the bark occurs, not at the cambium region, but in partly differentiated xylem. This fact may have considerable practical significance in explaining the poorer results secured with overseasoned wood.

Summary

1. The patch bud is the principal method employed in the propagation of the pecan, and storage budwood is used as a source of buds more extensively than any other kind.
2. The most effective seasoning temperature was found to range from 80° to 85° F. Sufficient moisture in insulating material only to prevent desiccation was found to be satisfactory for seasoning, and higher moisture contents were no more effective in stimulating the process.
3. Budwood cut relatively late in the dormant period seasoned in a shorter time than that cut early. Budwood of the Delmas variety seasoned more readily than that of the Stuart.
4. An influence regulates the cambial activity and the resulting slipping of the bark of budwood, similar to the one which prescribes the rest period of plants.
5. Peeling of bark involved in seasoning may occur prior to visible changes in size or shape of cambial cells.
6. In wood overseasoned in the dark, buds expand, water vessels differentiate and lignify, and starch disappears. When bark of over-seasoned wood separates from the wood, the line of splitting is not along the region of the cambium cells, but next to the xylem, the result apparently being that partly-differentiated cells go with the bark to interfere with its union with the stock.

7. The type of cambial activity which results in the formation of water vessels is first initiated in the base of a budstick, but very soon extends to the terminal.
8. Development of vessels seems to be dependent upon bud growth, even though the contemporary process of photosynthesis is not involved. Vessels do not develop in disbudded portions of partially or completely disbudded scions.
9. Seasoned budwood kept in cold storage can be preserved in a viable condition for at least a period of from three to four weeks. During this storage period there are no visible changes in structure of cambial cells, nor of the amount of starch indicated in the different starch-containing tissue of the stem.

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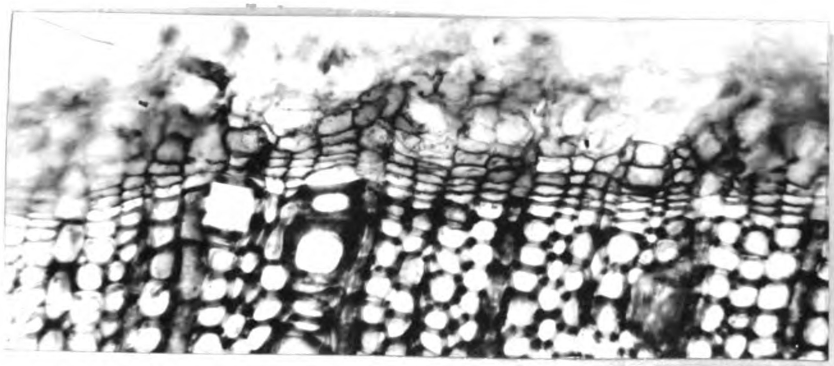


Plate 1 - Showing cambium region characteristic of dormant pecan budwood.

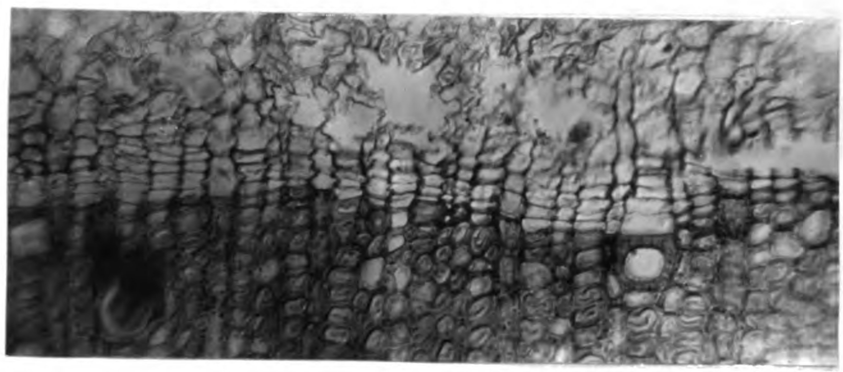


Plate 11 - Showing cambium region characteristic of seasoned pecan budwood.

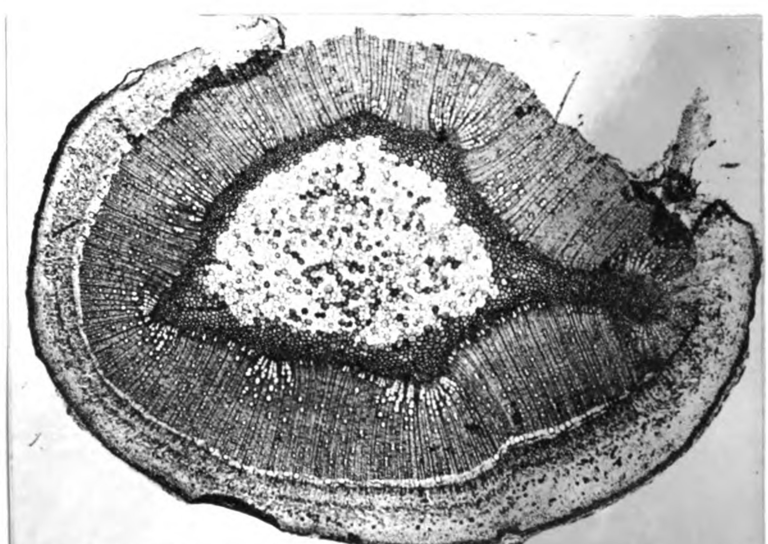


Plate 111 - Cross-section of budstick, showing leaf traces and location of vessels with relation to them.

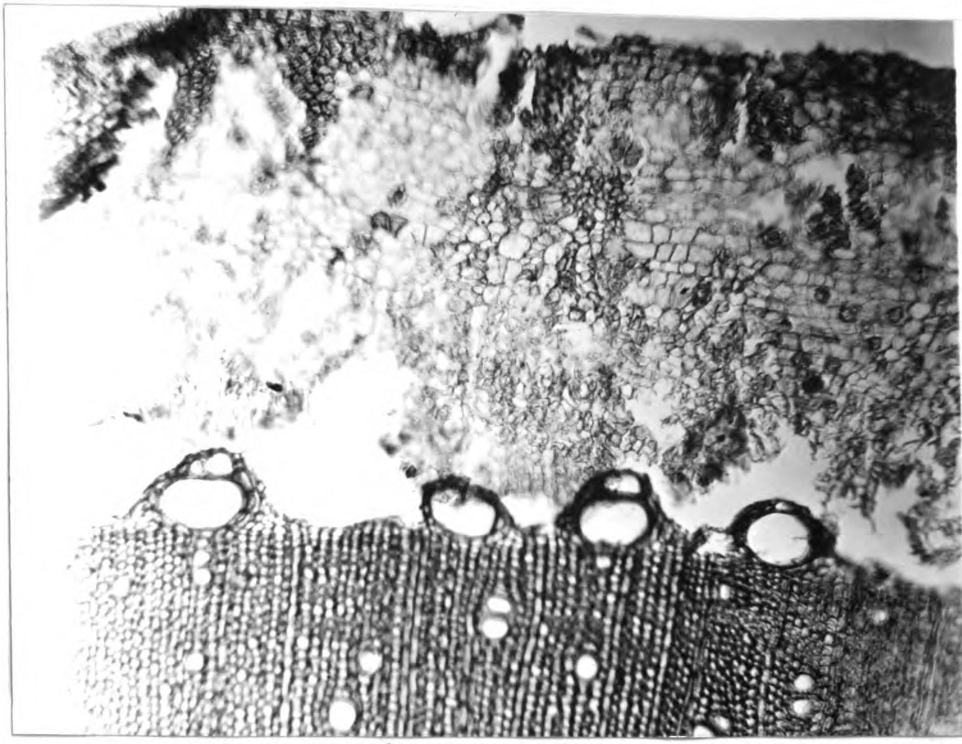


Plate IV - Transverse section from terminal portion of pecan budstick after 28 days of seasoning.

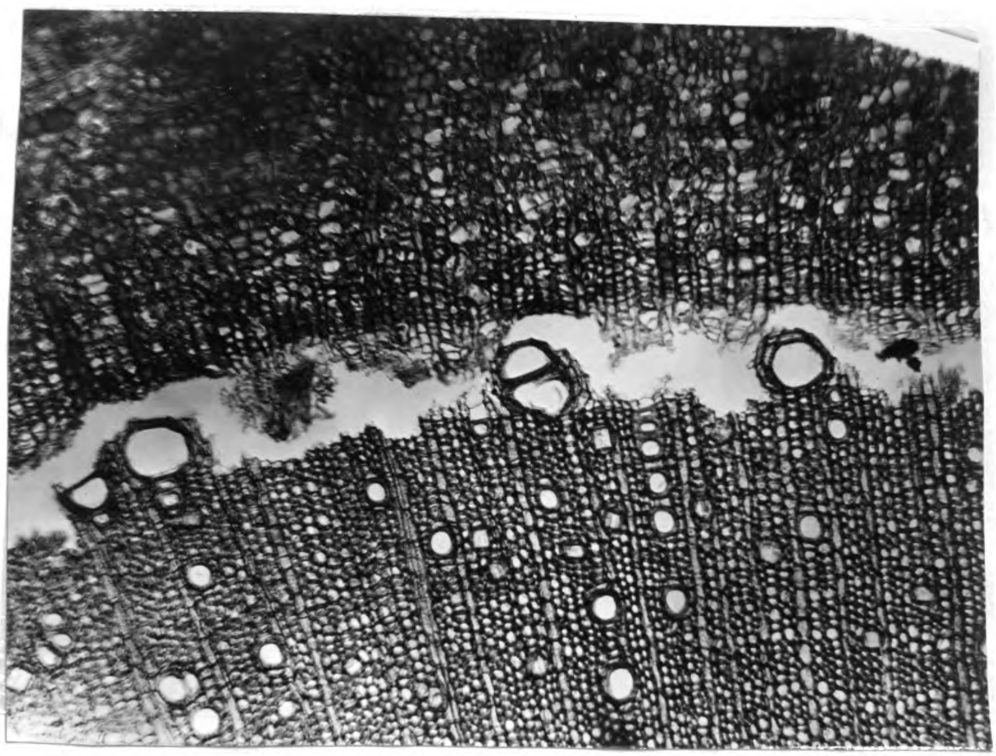


Plate V - Transverse section from basal portion of pecan budstick after 28 days of seasoning.

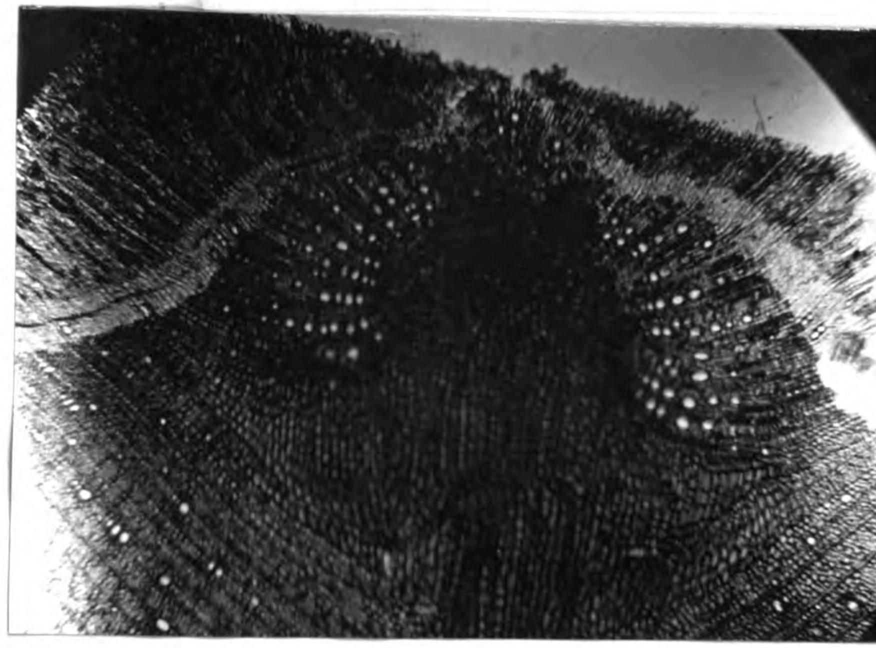
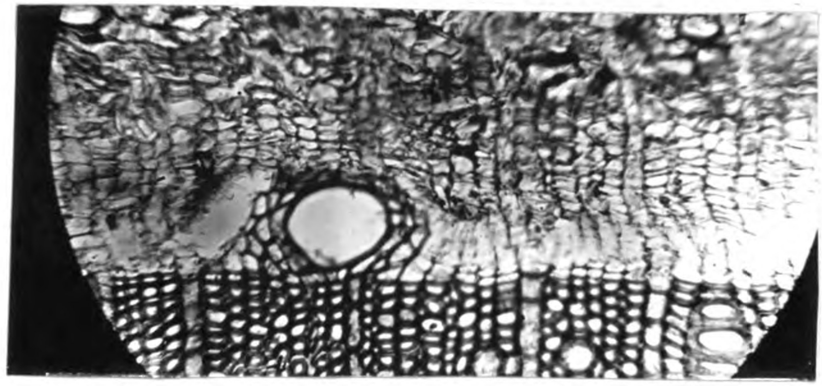
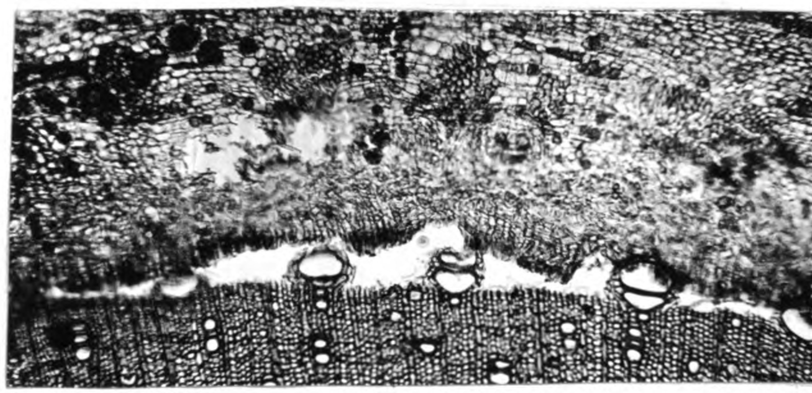


Plate VI - Transverse section showing location of vessels with reference to leaf traces. (See also Plate III.)

Plate V11



(A) - Lignified vessel between xylem and cambium of overseasoned budwood. Partly-differentiated cells on each side (tangentially) of the vessel. (Note cambium cells)



(B) - General view of transverse section of overseasoned budwood, showing line of splitting when bark separates from wood.

(C) - Note that the line of splitting is at the annual ring except where vessels occur. Several radial layers of partly-differentiated cells intervene between the line of splitting and the cambium.

Plates V111 - X11: Transverse sections of material seasoned 16 days.

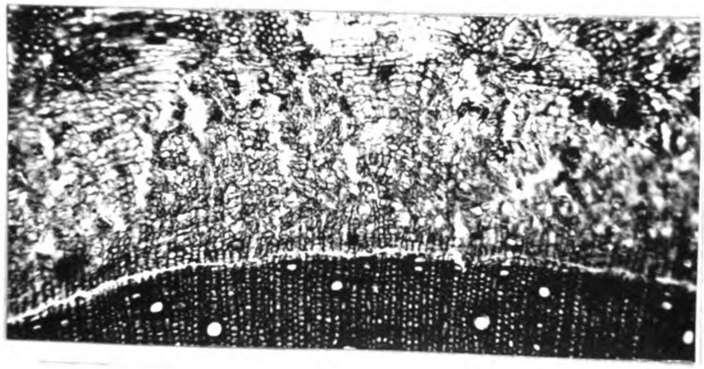


Plate V111 - Completely disbudded

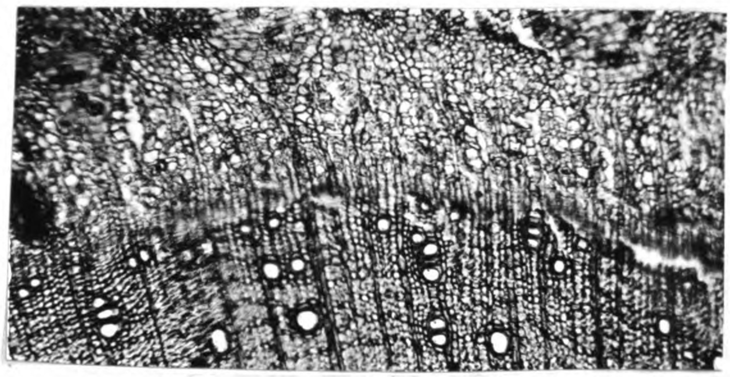


Plate 1X - Terminally disbudded, section from terminal portion.

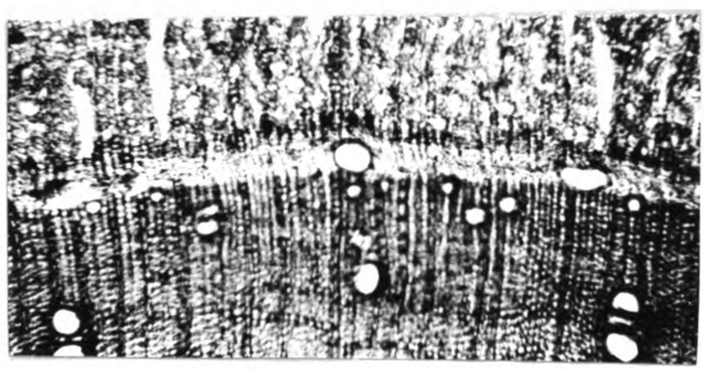


Plate X - Basal section of terminally disbudded budstick.

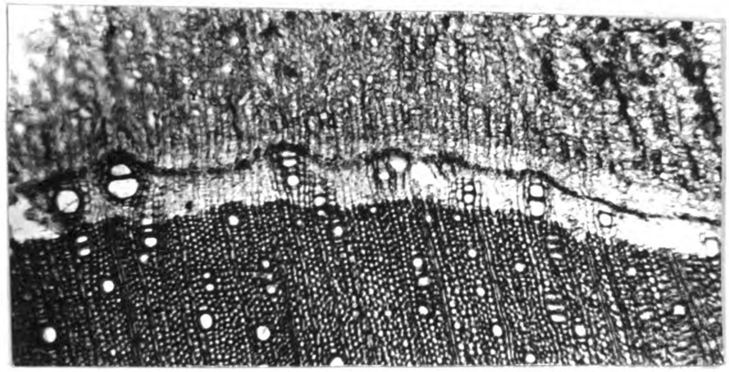


Plate Xl - Terminal section of bud-
stick, the basal part of
which had been disbudded.

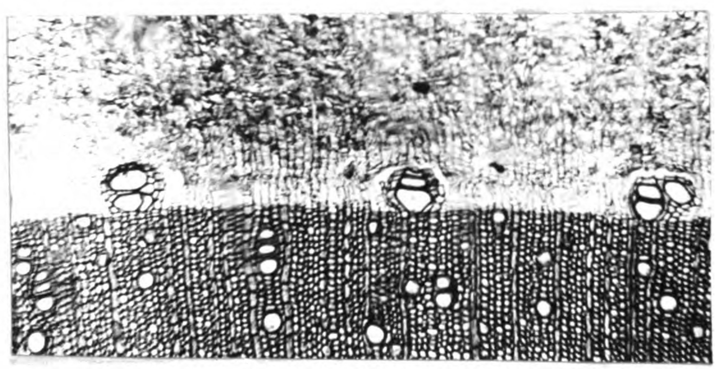


Plate Xll - Basal portion of budstick,
basal half of which had
been disbudded.

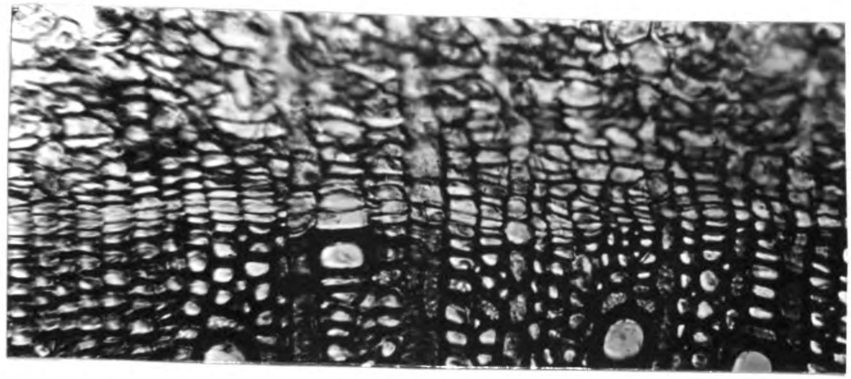


Plate XIII - Transverse section of budstick, seasoned normally and then held in cold storage for 28 days.

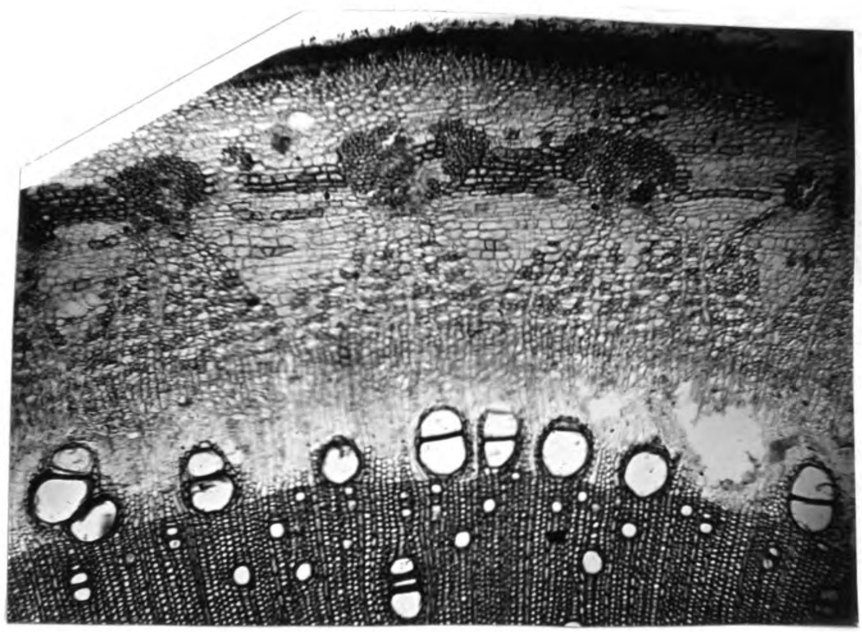


Plate XIV - Transverse section of budstick cut fresh from tree when current season shoots were from 6 to 10 inches long.

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