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COLLEGE STATION, BRAZOS COUNTY, TEXAS

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DIVISION OF HORTICULTURE

The Storage and Seasoning of Pecan Bud Wood

AGRICULTURAL AND MECHANICAL COLLEGE OF TEXAS

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The patch bud is the principal means employed in the propagation of the pecan by graftage. Buds of the current season may be used, but the work can begin much earlier if buds of the previous season are used. Such bud wood may be taken from the trees as needed, but it has been found to be more economical to cut the bud wood while dormant and keep it in cold storage. It is then "seasoned," or brought into condition for use by providing suitable conditions of moisture and holding at 80° to 85° F. Seasoned wood can be returned to cold storage and will remain ready for use at a later date.

It has been found that bud wood cut late in the dormant period seasons in a shorter time than that cut early. Bud wood of the Delmas variety seasons more readily than that of Stuart under comparable conditions. The time required for seasoning is also influenced by the date at which the process occurs, being shorter in late than in early spring.

There is evidence that bud wood held at a temperature exceeding 40° F. deteriorates with age, because of a depletion of the food supply. Results of studies on cambium activity, starch transformation, and on the effect of disbudding are presented, together with a discussion of the relationship of the seasoning process to the normal rest period in the pecan.

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BULLETIN NO. 478 AUGUST, 1933

THE STORAGE AND SEASONING OF PECAN BUD WOOD*

FRED R. BRISON

Propagation of named varieties of the pecan was started as early as 1885 by a few nurserymen, principally of the southeastern states. A report in 1901 of experiments conducted by the United States 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 in the propagation of walnuts prior to and during that time, and have since been used also on the hickories. It seems reasonable, then, to presume that these methods were also used in the propagation of pecans during the latter part of the 19th century.

In 1912, Van Deman (22) stated that grafting and budding were employed in nut-tree propagation. Tongue, or splice, and cleft graft were used, and the patch bud was satisfactory, but 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. J. A. Evans (7) in 1920 demonstrated that patch buds could be successfully inserted in rough thick bark of limbs three or more inches in diameter. This possibility renders it especially valuable for top-working poor- or non-producing trees that range in diameter from one to six inches.

Stuckey and Kyle (21) 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 top-working 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 present time. Incidentally, the use of the patch bud is no recent contribution to the art of plant propagation. Columella (4), about 23 A. D., described this method of graftage, "* * * 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 convinces one that he was referring to the patch bud.

THE PATCH BUD AND ITS USE

Essentially, patch budding consists of removing a piece of bark approximately seven-eighths of an inch square from the stock and inserting into its place bark containing a bud from the tree that it is desired to

*This investigation was conducted in cooperation with the School of Agriculture, A. and M. College of Texas, and the material in this Bulletin was also presented to the Michigan State College as a thesis for the degree of Master of Science.

propagate. It is considered important to have the bark of the inserted bud fit snugly at the top, bottom, and at least one side. Buds are tied firmly in place and grafting wax or similar material is usually applied to exclude moisture and air. Union between the bud and stock is accomplished by regeneration where the two cambiums are in close contact and by overwalling at the margins. Satisfactory growth results from both types of union.

The patch bud is found useful in the commercial propagation of seedling trees in the nursery row. It is also used in the top-working of older trees by inserting the buds in the rough bark of limbs that are one inch to two inches in diameter. This procedure in general is not recommended for trees that are larger than six or eight inches in diameter. Trees of larger sizes are cut back during a dormant season and allowed to force out young shoots which may be budded during the latter part of the summer following the winter in which the trees were cut back.

TYPES OF BUD WOOD

Current Bud Wood

In the commercial propagation of the pecan, both current and preceding season's growth are used. Wood of the current season's growth is suitable from midsummer until the end of the budding season. Buds from this type of bud wood are known as "current season" buds. On account of their immaturity they cannot be used earlier than perhaps June 15 with any assurance of reasonable success in even the most southern localities.

Fresh Bud Wood

Previous season's wood must, of necessity, be relied upon for spring and early summer budding. There are two principal ways in which such bud wood is handled prior to its use. One practice involves the cutting of the bud wood directly from the trees as it is needed throughout the budding season. This is known as "fresh" bud wood. An objection to the use of bud wood of this type is that in the spring many of the most valuable buds are forced into growth, either forming twigs or falling off, before the bud wood can be used. This is especially true of the western varieties. The eastern varieties, on the other hand, produce two to five buds at each node, occasionally more. Even though the largest and most valuable bud of the group may have advanced too far to be used, others are present which when forced properly may be depended upon for satisfactory growth. Such secondary buds, however, do not grow as quickly nor as vigorously as primary buds. In addition to the foregoing, seasonal conditions such as abundant rainfall or late spring frost may force practically all the suitable buds of a tree into growth and render them useless for budding purposes. Thus fresh bud wood is a dependable source of buds for use only during a relatively short period in the early spring. It cannot be relied on for late spring and early summer work.

Storage Bud Wood

The other method of handling bud wood of previous season's growth involves the cutting of scions about 12 to 18 inches long from trees during the dormant season and storing them, properly insulated against desiccation, at a temperature of 32° to 38° F. Bud wood handled in this way will be referred to hereafter as "storage wood." Since it is cut while dormant and is favored by a low temperature, it remains in a dormant condition in storage; hence it must be subjected to conditions upon removal that will permit the slipping of the bark before it can be used. This process, known as "seasoning," is accomplished by providing moisture and a warm atmosphere. It is considered that bud wood is seasoned when the bark may be readily peeled from the wood.

Propagators frequently experience difficulty in getting bud wood to season properly. Of the factors which may be associated with delayed seasoning, temperature and humidity during season and time of cutting bud wood from trees may be suggested. Practices with regard to each of these factors vary widely in commercial work.

INFLUENCE OF HUMIDITY ON SEASONING

Recommendations as to optimum water conditions during seasoning vary widely and have been rather indefinite. Ordinarily the insulating material is kept "moist but not wet." Hutchins (11) suggests "a mixture consisting of equal proportions of wet and dry sawdust or shavings" as satisfactory insulations for bud wood in storage or during seasoning. Woodward (23) advises placing the bud wood in water at a temperature of 90° to 100° F. and intimates that it will then season within two to four hours.

Two series of tests were conducted to determine the influence of humidity upon the seasoning process:

Three lots of Stuart bud wood, each containing 26 bud sticks, were seasoned in sphagnum moss to which the following additions of water per 100 grams of moss were made respectively: (a) 688 cc., (b) 344 cc., and (c) 172 cc. (Water was added to moss until conditions considered optimum were reached. The amount of water added was then determined to have been 688 cc.; one-half this amount was added to a second lot, and one-fourth to the third lot.) In each instance waxed paper was used to wrap individual packages in order to restrict evaporation and maintain the respective moisture content suggested above. This test was duplicated with the Delmas variety. Somewhat later 24 bud sticks of the Stuart variety were placed for seasoning in moss that contained 1000 cc. of moisture per 100 grams of moss; and a duplicate lot of 24 bud sticks was placed in moss that contained only 150 cc. of water to each 100 grams of moss. In each test, bud wood seasoned in the same length of time regardless of the relative moisture content of the moss.

These results show that the amount of moisture may vary widely without retarding the seasoning process. Bud wood seasons in as short a period in relatively dry moss as in moss that is decidedly wet. It is known, however, that some moisture is essential and it is evident that its chief beneficial effect is associated with the prevention of desiccation.

The results given above are consistent with those of Shippy (19), who with respect to the callusing of apple cuttings, 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 have little or no stimulating effect on callus formation * * *."

A limited number of tests were conducted in which bud sticks were half submerged in vertical position, some upright and others inverted, in pails of water. In no instance did the submerged portions of a bud stick season, although in every instance exposed parts of bud sticks seasoned normally. It seems likely that the inability of submerged parts of scions to begin activity was due to lack of proper aeration. Further, it has been the experience of the writer that the practice of soaking bud wood in water does not hasten the seasoning process.

It is of incidental interest that bud sticks do not seem to change in weight to any appreciable extent during this process. In two tests in which 64 bud sticks were weighed carefully before and after seasoning there was no consistent appreciable increase in weight during seasoning; in fact the weights of some bud sticks revealed slight losses.

INFLUENCE OF TEMPERATURE ON SEASONING

Little experimental work seems to have been done to provide a basis for regulating the temperature for seasoning bud wood. Burkett (3) recommends putting bud wood in wet moss, sawdust, sand, or other good material, and laying the insulated bud wood out in the sun until the bark slips. Woodward (23) advises total immersion in water at 90° to 100° F. for two to four hours.

Several preliminary attempts were made to season lots of bud wood at temperatures of 95° to 100° F. No attempt was fully successful. Of these lots, a limited number of bud sticks became partly seasoned, but no entire lot seasoned normally.

A series of tests was then initiated for the purpose of determining an optimum temperature for the seasoning process. Bud wood of the Stuart variety was cut in February and held in cold storage until the following May. On May 20 three lots of 8 sticks each were packed separately in sphagnum moss, to which water had been added at the rate of 688 cc. per 100 grams of moss. Each lot was then 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 from 63° to 68° F. The test was repeated, using 18 sticks in each lot, and substantially the same results were obtained. As may be seen from Table 1, bud sticks did not season normally at either the high or low range of temperature. They seasoned normally at temperatures ranging from 78° to 85° F., and throughout investigations

Table 1. Relation of temperature to seasoning

Total number bud sticks	Temperature	Results
26	63°-68° F.	All bud sticks dormant at end of 8 days.
26	78°-85° F.	24 bud sticks seasoned within 4 days.
26	93°-98° F.	7 bud sticks seasoned at end of 8 days.

here reported this range of temperature was found effective in seasoning bud wood.

RELATION OF TIME OF CUTTING BUD WOOD TO SEASONING

Definite information seems to be lacking on the possible relationship between the time of cutting bud wood and the length of time required for seasoning. Hutchins (11) mentions "from January to the latter part of February" as the season for cutting bud wood from trees; Burkett (3) recommends "late winter."

Between the 15th and 20th of each of the months of December, January, February, and March during the winters of 1928-29, 1929-30, and 1930-31, bud wood was taken from pecan trees of the Stuart and Delmas varieties in the orchard of the Department of Horticulture of the Agricultural and Mechanical 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 bud sticks obtained from these trees were approximately one-half inch in diameter at the base, 12 to 18 inches long, and had been formed during the previous growing season. In general, bud sticks used in this test were of a type considered ideal for the purpose of patch budding.

On the date each lot of bud wood was cut, it was packed for storage in sphagnum moss uniformly moistened with 688 cc. of water per 100 grams of moss. This wood was packed in open boxes and 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 budding each spring, samples of bud wood of each variety, cut from December through March, were taken out of storage and held for seasoning. Uniform conditions of moisture and temperature were provided by packing all the bud sticks used in a test in a single container. Sphagnum moss, with the same content as that used in storage, was used for insulation during seasoning. Waxed paper was employed to restrict evaporation of moisture although no attempt was made to make packages air-tight. When packed, the boxes were placed in a steam heated room, the temperatures of which could be maintained rather accurately at 80° to 85° F.

The bud wood was inspected at intervals and records were taken on all comparable lots on the date a considerable percentage of bud sticks of any lot became fully seasoned. The proportion of bud sticks seasoned on this date has been used as an index of the rate of seasoning for each lot.

Results of all tests conducted for the purpose of determining the relationship between time of cutting bud wood of the Stuart variety and the rate of seasoning are summarized in Table 2. Inspection of results presented

Table 2. Relation between time of cutting bud wood and length of time required for seasoning (Stuart)

Total number bud sticks	Date seasoning began	Date test completed	Cut in December		Cut in January		Cut in February		Cut in March	
			Number		Number		Number		Number	
			tested	sea-soned	tested	sea-soned	tested	sea-soned	tested	sea-soned
6	5-20-29	5-25-29	2	0	2	0	2	1	—	—
6	5-20-29	5-27-29	2	0	2	0	2	1	—	—
16	5- 1-30	5- 3-30	4	1	4	4	4	4	4	4
16	5- 7-30	5- 9-30	4	1	4	2	4	2	4	4
16	5-16-30	5-17-30	4	1	4	1	4	0	4	4
18	2-18-31	3- 3-31	6	1	6	0	6	3	—	—
40	3-18-31	3-27-31	10	1	10	0	10	4	10	10
72	5- 4-31	5- 6-31	18	5	18	5	18	17	18	18
Totals			50	10	50	12	50	32	40	40

in that table shows that seasoning of Stuart bud sticks cut relatively late in the dormant period takes place in a shorter time than is required for those cut early. Of 50 bud sticks cut in December only 10 were seasoned when the respective tests were concluded. Twelve of 50 cut in January, 32 of 50 cut in February, and 40 of 40 cut in March were seasoned during comparable tests.

Differences in the response of Delmas bud wood cut at monthly intervals to seasoning conditions are less pronounced than those recorded for Stuart. The totals given in Table 3 show that 30 of 50 bud sticks cut in December, 45 of 50 cut in January, and all that were cut in February and March were seasoned upon completion of the respective tests.

In view of the fact that Delmas responded more readily to conditions of seasoning throughout this test, it is probable that if data on seasoning had been recorded a few days earlier for each lot, differences in response of Delmas wood cut early and late would have been more pronounced.

RELATIVE RESPONSE OF STUART AND DELMAS IN SEASONING

Comparison of Tables 2 and 3 shows a varietal difference in the response of the two varieties to seasoning conditions. Of a total of 50 bud sticks of each variety cut in December, 30 Delmas bud sticks were seasoned when the data were recorded as compared with 10 Stuart; likewise of bud wood cut in January, 45 Delmas were seasoned as compared with 12 Stuart, and of that cut in February, all 50 of the Delmas and only 32 of the 50 Stuart bud sticks were seasoned. The results as summarized in Table 4 emphasize these differences. It is evident that Delmas is more sensitive than Stuart in its reaction to moisture, temperature, and to whatever other factors which tend to initiate the seasoning process.

Table 3. Relation between time of cutting bud wood and length of time required for seasoning (Delmas)

Total number bud sticks	Date seasoning began	Date test completed	Cut in December		Cut in January		Cut in February		Cut in March	
			Number		Number		Number		Number	
			tested	seasoned	tested	seasoned	tested	seasoned	soned	tested sea-
6	5-20-29	5-25-29	2	1	2	1	2	2	—	—
6	5-20-29	5-27-29	2	0	2	2	2	2	—	—
16	5- 1-30	5- 3-30	4	4	4	4	4	4	4	4
16	5- 7-30	3- 9-30	4	4	4	4	4	4	4	4
16	5-16-30	5-17-30	4	3	4	4	4	4	4	4
18	2-18-31	3- 3-31	6	5	6	5	6	6	—	—
40	3-18-31	3-23-31	10	0	10	8	10	10	—	—
72	5- 4-31	5- 6-31	18	13	18	17	18	18	—	—
Totals			50	30	50	45	50	50	12	12

This seems particularly interesting since normally the growth of Delmas trees is prolonged later in the 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 to harvest from the 10th to the 15th of October. This constitutes an objectionable feature of the Delmas variety since its fruit ripens so late in the season that the crop is sometimes ruined by early frosts. Yet Delmas bud wood cut in December and January is more responsive to seasoning than bud wood of the Stuart variety cut at that time.

The fact that Delmas trees initiate growth earlier in the spring than Stuart is interesting and no doubt significant also in this connection. Ordinarily by the 10th of March, Delmas trees are showing signs of growth. Bark of fresh bud wood material of this variety slips readily at that time and the wood is not considered suitable for storage purposes. It was on this account that Delmas bud wood was not stored in March in 1929 and 1931. Stuart bud wood, on the other hand, seemed to be in a dormant condition each year until after March 12. Hence bud wood of Delmas would be expected to season more rapidly than that of Stuart.

Histological cross-sections of dormant and seasoned bud wood of both Stuart and Delmas at different periods from December to May show no differences between the two varieties in the appearance of the cambium region. This and studies on starch translocation will be considered in later sections.

Table 4. Comparison of responses of Stuart and Delmas pecan bud wood to conditions *considered favorable to seasoning*

Date cut	Date seasoning began	Number days seasoned	Stuart		Delmas	
			Number bud sticks in test	Number bud sticks seasoned when test completed	Number bud sticks in test	Number bud sticks seasoned when test completed
12-14-28	5-20-29	5	2	0	2	1
1-14-29	5-20-29	5	2	0	2	1
5-21-29	5-20-29	5	2	1	2	2
12-14-28	5-20-29	7	2	0	2	0
1-14-29	5-20-29	7	2	0	2	2
2-21-29	5-20-29	7	2	1	2	2
2-21-29	5-20-29	5	2	1	2	2
2-21-29	5-20-29	5	2	2	2	2
2-21-29	5-20-29	5	2	2	2	2
2-21-29	5-20-29	5	2	1	2	2
2-21-29	5-20-29	5	2	0	2	2
2-14-30	2-14-30	10	3	0	3	3
12-20-29	5- 1-30	2	4	1	4	4
1-20-30	5- 1-30	2	4	4	4	4
2-20-30	5- 1-30	2	4	4	4	4
3-10-30	5- 1-30	2	4	4	4	4
12-20-29	5- 7-30	2	4	1	4	4
1-20-30	5- 7-30	2	4	2	4	4
2-20-30	5- 7-30	2	4	2	4	4
3-10-30	5- 7-30	2	4	4	4	4
12-20-29	5-16-30	1	4	1	4	3
1-20-30	5-16-30	1	4	1	4	4
2-20-30	5-16-30	1	4	0	4	4
3-10-30	5-16-30	1	4	4	4	4
12-18-30	2-18-31	15	6	1	6	5
1-18-31	2-18-31	15	6	0	6	5
2-18-31	2-18-31	15	6	3	6	6
12-18-31	3-18-31	5	10	1	10	1
1-18-31	3-18-31	5	10	0	10	8
2-18-31	3-18-31	5	10	4	10	10
12-18-30	5- 4-31	2	18	5	18	13
1-18-31	5- 4-31	2	18	5	18	17
2-18-31	5- 4-31	2	18	17	18	18
Totals			175	74	175	151

NUMBER OF DAYS FOR SEASONING BUD WOOD DURING DIFFERENT MONTHS

It has been shown that bud wood cut late in the winter seasons in a shorter period of time than bud wood cut early in the winter when both are seasoned at the same time. Since seasoning the bud wood was not all done at one time there was opportunity to determine the relationship of the month of seasoning to the rate at which this process occurs.

Bud wood of Stuart and Delmas varieties was cut in December and held in cold storage until needed. Optimum seasoning conditions were provided for representative lots in December, January, February, March, and May. The attempt at seasoning during December resulted in death of all scions of each variety by the end of 20 days. Bud wood of both varieties seasoned in January in a period of 19 days. Delmas bud wood of the same lot seasoned in 15 days during February, and in only 2 days after removal from storage in May (Table 5). Delmas bud sticks cut in February seasoned in 15 days in February, 5 days during March, and only 2 days in May.

Data showing response of Stuart bud wood do not suggest so clearly a relationship between number of days required for seasoning and the date

Table 5. The number of days required for seasoning bud wood on successive dates during the budding season (1931)

Variety	Date cut	Seasoning begun (60 days after December 18) Feb. 18, 1931				Seasoning begun (90 days after December 18) Mar. 18, 1931				Seasoning begun (136 days after December 18) May 4, 1931			
		Days in storage	Number days tested	Number bud sticks	Number seasoned	Days in storage	Number days tested	Number bud sticks	Number seasoned	Days in storage	Number days tested	Number bud sticks	Number seasoned
Stuart	12-18-30	60	15	6	1	90	5	10	1	136	2	18	5
Stuart	1-18-31	30	15	6	0	60	5	10	0	102	2	18	5
Stuart	2-18-31	0	15	6	3	30	5	10	4	76	2	18	17
Stuart	3-18-31	—	—	—	—	0	5	10	10	46	2	18	18
Delmas	12-18-30	60	15	6	5	90	5	10	0	136	2	18	13
Delmas	1-18-31	30	15	6	5	60	5	10	8	106	2	18	17
Delmas	20-18-31	0	15	6	6	30	5	10	10	76	2	18	18

at which this process occurs, as shown by Table 5. It is significant, however, that of the Stuart bud sticks cut in February only 3 of 6 seasoned in 15 days in February, whereas 17 of 18 bud sticks of the same lot seasoned in 2 days in May, after having been in cold storage 76 days. 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 temperatures for each lot ranged from 80° to 85° F.

STORAGE OF SEASONED BUD WOOD

Seasoned bud wood 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 bud wood was in good condition for use. At the end of 9, 16, 23, and 37 days buds were taken from this lot and inserted in nursery stock. Of a total of 16 buds, 13 were found to be successful, 1 failure was recorded, and the identity of 2 others was lost. It was significant that 3 out of 4 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 bud wood 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 bud wood 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 6, show that it is possible to hold seasoned bud wood of the varieties indicated in cold storage for a period of at least 18 to 25 consecutive days without a significant decrease

Table 6. The longevity of storage bud wood held in cold storage after seasoning

Number days in storage	Number buds* set	Number buds growing	Per cent of buds growing
4	85	61	71+
11	138	106	76+
18	126	98	77+
25	124	82	66+
over 30	44	22	50+

*Total of buds from Burkett, Delmas, Schley, Stuart, and Sovereign (Texas Prolific).

in the number of buds that will grow when used for propagation purposes. The buds made no apparent growth in storage. The type of cambial activity that results in slipping of bark, stimulated during the seasoning process, did not proceed to the extent that new cells formed in storage, though the bark continued to slip during the entire storage period. Cross sections from lots of seasoned bud wood that had been held in cold storage for 28 days showed a cambium region indistinguishable from that of normally seasoned bud wood. No decrease in amount of starch in any of the tissues was apparent at that time. In contrast to this, buds held at 80° to 85° F. for 28 days had grown out an inch or more. The starch had disappeared from all tissues held at the higher temperature and sections from it show that new vessels had formed.

The practical utility of holding seasoned buds in storage appears especially significant when it is remembered that nurserymen and propagators frequently experience difficulty in getting bud wood to season at the proper time. This difficulty may be due to cool weather or lack of consistency in the response of bud wood 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 bud wood; likewise it happens that the use of bud wood is often delayed by rain or other unfavorable weather conditions, or by other causes; in such cases it deteriorates. It is more convenient to have bud wood seasoned and ready for use than to have to anticipate a need for it and make preparations for its use 3 or 4 days or a week ahead of time. Further, nurserymen who follow a practice of selling bud wood might be expected to have a greater demand for wood than can be used on delivery than for wood that will require a period of seasoning.

Some preliminary work in storing fresh wood indicates that such wood can be held practically as long as seasoned wood. Here, however, the utility involved is not so much a matter of convenience as the probability of getting better buds at the time they would be stored than might be available later in the season.

STUDIES RELATING TO INTERNAL CHANGES INVOLVED IN SEASONING

The varietal response of bud wood in seasoning suggests clearly that factors other than those of environment influence the process. For this reason an attempt was made to determine the more obvious internal changes that occur in connection with the seasoning process. This involved rest-period investigations and a study of starch translocation, vessel development, and the connection of bud enlargement with these processes.

Relationship of Rest Period to the Time Required for Seasoning

It has been shown that the length of time required for seasoning is dependent among other things upon the date of cutting the bud wood, upon the date of seasoning, and upon the variety used. These facts suggest a definite relationship between the process of seasoning and the natural breaking of the rest period in spring.

Such a relationship has not been fully established, however, since the seasoning process involves primarily the cambium region while most rest-period studies have been concerned with bud activity, with diameter increase, or with the reaction of cambium near wounds. On the other hand, the small amount of definite study of cambium behavior in rest-period investigations would seem to indicate the possibility that it follows the behavior exhibited by buds.

Jost (12) cites Hartig as showing that callus formation and root development in cuttings, both products of cambium activity, occur during the rest period. In addition, Jost reports experiments of his own leading to the same general conclusions.

Simon (20) observed that callus formed 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 not in the resting condition. He concludes that the rest period is not a time of complete inactivity but simply one during which only certain growth functions are brought to a standstill and that respiration and certain other physiological functions, so far as not inhibited by outer conditions, continue their course.

Curtis (5) believes that true rest of woody cuttings is shown only by buds and that callus formation, root development, and root growth are independent of the rest period. In reporting the behavior of *Ligustrum ovalifolium* cuttings treated with potassium permanganate solutions he considers that the treatments did not break the rest period of the whole cutting, since bud development was alike on treated and untreated cuttings.

Perhaps it is because a great deal of the 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 (9) that species of Hicoria are refractory in regard to ending the rest.

The difference in seasoning of bud wood cut early and that cut late (Tables 2 and 3) indicates that removing wood from the tree and storing it at temperatures slightly above freezing delays the breaking of the rest period of the cambium, 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. The fact that wood cut on a given date, early or late, seasons in a shorter period in late spring than in late winter, shows 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.

During the rest period, callus forms freely at cut surfaces during seasoning and bark slips in the region of a wound before the entire bud stick becomes seasoned. Apparently then wounding is a treatment that ends, directly or indirectly, the rest period of the cambium. It will be observed later that expanding buds have the same effect.

Certain rest-breaking treatments were used early in January of 1932 on Delmas and Stuart bud wood cut fresh from trees. Buds of wood that had been previously subjected to ether gas for 24 hours began vigorous growth before buds of the checks showed any signs of activity but etherization had no direct influence upon slipping of the bark. Buds of scions treated with ether grow and burst their scales before bark of the entire bud stick will slip; following bud growth, bark in regions adjacent to growing buds begins to slip and ultimately this region extends to include the entire bud stick. In contrast to this, in late spring after the rest period has ended normally the degree of cambial activity necessary for the slipping of bark precedes the bursting of buds. This is true of both storage bud wood and twigs which remain on the tree.

In brief, the studies herein reported show that cambium activity as measured by slipping of the bark before cell division begins, is limited by rest-period phenomena. Tests thus far indicate that the cambium and buds do not respond to the same rest-breaking treatments. It is conceivable, however, that the structure of the bud may render it more susceptible to the influence of ether than is the case with the secondary meristem which is protected by bark.

With some species, early advent of the rest period in the fall is regarded as favorable to early spring growth. Delmas, however, as has been previously suggested, prolongs its autumnal activity later and begins spring activity earlier than Stuart. It is obvious, then, that it has a shorter or less intense rest period than Stuart.

Relation of Cambial Activity to the Seasoning Process

Since seasoned bud wood is wood on which the bark slips freely and since seasoned bud wood quickly becomes overseasoned and thus useless for budding while the bark still slips freely, knowledge of the changes occurring in the cambium during and after seasoning seems desirable. Kundson (14) has shown that with the peach "cambial activity began * * * at the time of the opening of the buds," and Hastings (10) and Kobel (15) regard slipping of the bark as an index to cambial activity.

In this work studies were made of transverse sections representing (1) wood taken directly from the dormant pecan trees, (2) wood from cold storage, (3) wood sectioned at various stages of the seasoning process, (4) overseasoned wood, and (5) seasoned wood which had been returned to cold storage. 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.

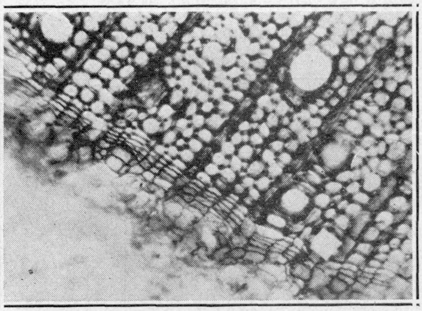

Fig. 1. Section from dormant storage bud-wood—Stuart variety.

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

Sections made from dormant bud wood (see Figure 1) show a cambium region of three to six cells in radial thickness, at different points within a section. In total thickness this tissue ranges 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 36 to 46 microns. It was somewhat difficult to distinguish the outer cells of the cambium from those that were, perhaps, the last-formed phloem cells.

In many instances there was a gradation in size and shape from the thin-walled, rectangular cells adjacent to 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 Tables 7 and 8. No significant differences between seasoned and dormant wood in radial extent of cambium and number of cells in radial thickness were evident (Figures 1 and 2).

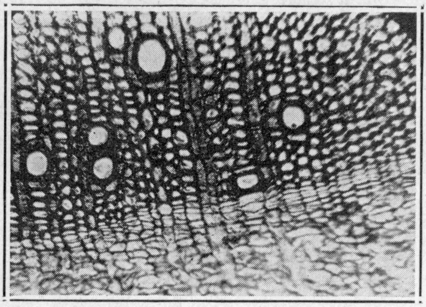

Fig 2. Section from Stuart bud wood seasoned after storage.

It is concluded that the bark is in condition to slip before cell division occurs in the cambium region. Support is given this view by unpublished observations of Prof. F. C. Bradford of the Michigan State College, on peach and apple.

Table 7. Radial thickness of cambium region of dormant and seasoned bud wood

Class limits microns	Number of observations	
	Dormant	Seasoned
28-37	25	16
38-47	26	38
48-58	22	19
58-67	2	3
68-77	2	1
	77	77
Mean	43.4±.74	44.1±.64

Several lots of bud sticks were allowed to continue the seasoning process until overseasoned. It is seldom that buds on normally seasoned wood show signs of beginning growth, and advancing buds characterize overseasoned wood. One lot of 24 sticks was removed from storage on April 22, and was in seasoned condition 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 8, 19, and 24 days after seasoning had occurred. During the entire period of 28 days following removal from storage the overseasoned lots were packed in a horizontal position in moist sphagnum moss and were kept in total darkness. Differentiated and lignified vessels interspersed between elements that were as yet incompletely differentiated had formed in both the terminal and basal parts of the bud sticks prior to the 12th day. By the 28th 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 (Figure 3); practically every trace of starch had disappeared from the tissues which formerly were loaded with it and buds had made 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.

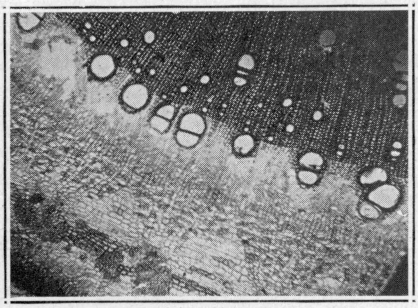

Fig. 3. Section from fresh bud wood cut directly from the tree in May; note development of vessels in the cambium region.

It is noteworthy that when the bark slips on overseasoned bud wood the line of splitting was not in the cambium but next to the xylem. Thus, it is indicated that when a patch is removed from overseasoned bud wood, elements that are yet incompletely differentiated are included with the bark. These prevent the cambium of the patch from being in close contact with the cambium of the stock and so interfere with union.

Table 8. Number of cells in thickness of cambial region in dormant and seasoned bud wood

Number cells	Number observed	
	Dormant	Seasoned
3	23	19
4	46	51
5	5	6
6	3	1
	77	77
Mean	3.84±.06	3.86±.04

Of the three leaf traces at a node, one is immediately beneath the buds; the other two are somewhat higher, though below the level of, and lateral to the buds of a node. 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 ones appear distinctly visible in each section. Two sets of traces may be recognized in sections that were evidently taken from portions of bud sticks on which the internodes were short.

In sections which clearly reflected only one set of leaf traces, vessels were more numerous in the half of the section which contained the traces. In sections which showed signs of two sets of leaf traces, an association of the distribution of vessels with traces was evident. A series of sections which clearly revealed only one set of traces showed an average of 24 vessels in the half of the section in which the traces occurred as compared with six 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 the half that contained the larger traces as compared with 20 for the other half. In another it was 18 as compared with 16.

These observations are in general accord with the findings of Jost (12) and with the statement of Priestly and Swingle (17), commenting on the work of Swabrick 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." They regard 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. How far below the bud this condition prevailed was not determined.

A comparison of the average number of vessels seen in 48-low-power fields of basal sections, representing 24 bud sticks, with the corresponding number in terminal sections, on successive dates is given in Table 9. Each

Table 9. Frequency of fibrovascular bundles in overseasoned bud wood

Days of seasoning	*Relative frequency of vessels	
	Basal	Terminal
12	5	1
23	10	15
28	14	23

*Average of two low-power fields from each of 24 sections.

observation was made from a portion of the section in which vessels were most numerous. These results, presented in Table 9, suggest that cambial activity, which results in vessel lignification, in the base of the pecan bud stick precedes the same process in the terminal portion. 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 basal portion. It should be noted, however, that in general buds on terminal parts of bud sticks advance in growth more rapidly than those on the basal part. Vessel lignification seems to occur simultaneously with the bursting of buds or to follow very soon thereafter.

In the case of bud wood it has seemed that all parts of the bark are in a condition to slip simultaneously. It will be shown later that the seasoning process may be initiated without the subsequent vessel lignification even in overseasoned wood.

Effect of Disbudding on Cambium Activity

R. Hartig, as cited by Jost (12), 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 normall antecedent to the formation of new wood.

Three lots of 6 bud sticks each were removed from storage, the sticks of one lot being completely disbudded. Only the terminal half of the second lot and the basal half of the third were likewise disbudded. With these preliminary treatments, they were placed in sphagnum moss for seasoning. Examination on the 6th day showed that all parts of the bud sticks, irrespective of treatments, were seasoned.

After 9 and 16 days, transverse sections were cut from terminal and basal portions of bud sticks that represented each of the treatments mentioned above. The sections representing the two dates were practically identical in what they showed with respect to cambial activity which results in development and lignification of vessels. Of the sections from disbudded sticks, (Fig. 4) none showed vessels; of those from terminally disbudded sticks, basal sections showed vessels (Fig. 5), while terminal sections did not; and of those from sticks the basal parts of which had been disbudded, basal sections showed vessels on the 9th day and terminal sections did not, while by the 16th day both basal and terminal sections showed vessels.

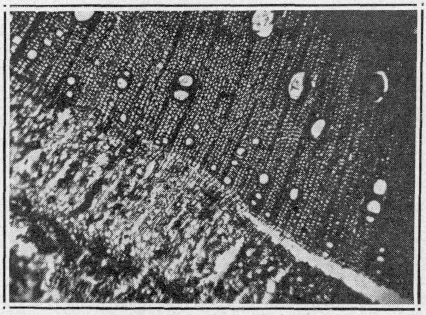

Fig. 4. Section from disbudded seasoned scion; no vessels have developed.

Counts of the number of vessels in each of 3 to 10 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 presented in Table 10.

It is concluded from these data that expanding buds, even though they are not 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 the basal half do not exert a similar influence on disbudded terminal parts.

Relation of Starch Transformation to Seasoning

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 test, this was used as a means of comparing growth-resumption phenomena in seasoned and in normal bud wood. 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.

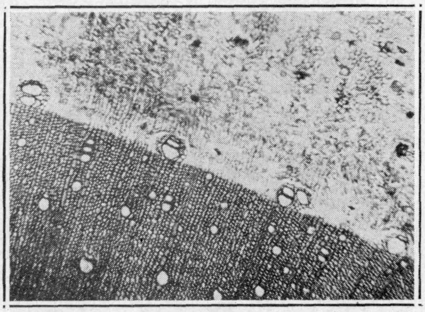

Fig. 5. Section from a disbudded basal half; note the vessels in the cambium region, due to the influence of buds in the terminal portion.

Mer (16) 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 shoot. 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 (18), 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

Table 10. Number of vessels in disbudded wood after 16 days of seasoning

Treatment	Range in number 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

wood parenchyma, then from wood fibers, pith sheath, and from the center 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 bud wood. They were cut to a thickness of 25 to 30 microns, treated with a 5 per cent 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 bud wood throughout the storage period.

In general, clusters of starch grains appeared abundantly in the periphery of the pith, in medullary rays from pith to cambium, and in xylem parenchyma. If starch was present in cells outside of 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 xlem parenchyma, another only a trace, or none at all. The extent to which these differences affected seasoning was not determined. Reichardt (18) 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 sections of any of the following: (1) dormant bud wood from storage, (2) dormant bud wood cut from trees, (3) normally-seasoned wood from storage, (4) seasoned bud wood which had been returned to cold storage and held three weeks, (5) fresh bud wood cut just prior to the beginning of growth in spring, and (6) fresh wood cut when current growth was six inches long and catkins were nearly mature.

These observations, in so far as they apply to dormant bud wood and seasoned bud wood prior to growth of buds, are in accord with the conclusion of Reichardt (18) 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 bud sticks which had seasoned 28 days and consequently were overseasoned 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 preceived in the whole internode," and "in the twigs which grew in the dark, after a month all starch was exhausted." Jost (12) 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 partly in diameter increase since new vessels formed in the meantime, 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 bud wood 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 bud wood. These sections showed the usual 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 10 to 18 inches and in many cases had set fruit, and several layers of the new xylem had been laid down, showed no trace of starch in any of the starch-containing tissues.

Starch tests were made on bud sticks that had been given 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 16 days. It will be recalled that starch disappearance from overseasoned wood was recorded at the end of a considerably longer period,—28 days.

In short then, the starch in pecan wood disappears with the beginning of growth. This is a transformation common to most deciduous trees, and the behavior of seasoned bud wood in this respect seems identical with that of normal bud wood. The absence of pronounced starch changes may be tentatively assumed as indicating absence of pronounced changes in fats, since in most woody plants, according to Fischer (8), there seems to be a rough reciprocal relationship between the two during the winter months.

RECOMMENDATIONS

1. Bud wood should be cut for storage from trees late in the dormant period, perhaps only ten days or two weeks before the trees are expected to show first signs of growth.

2. A temperature of 32° to 40° F. is effective in preserving bud wood in cold storage and in keeping it dormant.

3. Stored bud wood should be packed in material kept sufficiently moist to prevent drying.

4. A temperature of 80° to 85° F. is recommended as being most suitable for quick seasoning.

5. Only enough moisture in the packing material used for insulation during seasoning to prevent drying of bud sticks is necessary. Additional moisture does not hasten the process.

6. Bud wood stored while dormant and later seasoned should be returned to storage (temperature 32° to 40° F.) if it is not to be used within two

or three days. Having been stored, it may be used over a period of 18 to 25 days without deteriorating greatly in value as a source of buds.

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SUMMARY

1. Eighty to eighty-five degrees Farenheit is recommended as the most effective temperature for seasoning.

2. Just enough moisture in insulating material to prevent desiccation was found to be satisfactory for seasoning, and higher moisture contents were not more effective in stimulating the process.

3. Bud wood cut relatively late in the dormant period seasoned in a shorter time than that cut early. Bud wood of the Delmas variety seasoned more readily than that of the Stuart.

4. Bud wood seasons in a shorter time in late spring or early summer than in early spring following the storage period.

5. Seasoned bud wood in cold storage can be preserved in a viable condition for at least a period of 18 to 25 days. 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.

6. An influence similar to the one which prescribes the rest period of plants regulates the cambial activity and the resulting slipping of the bark of bud wood.

7. Peeling of bark involved in seasoning may occur prior to visible changes in size or shape of cambial cells.

8. In wood overseasoned in the dark, buds expand, water vessels differentiate and lignify, and starch disappears. When bark of overseasoned wood separates from the wood, the line of splitting is not along the region 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.

9. The type of cambial activity which results in the formation of water vessels is first initiated in the base of a bud stick, but very soon extends to the terminal portion.

10. Development of vessels seems to be dependent upon bud growth, even though the contemporary process of photo-synthesis is not involved. Vessels do not develop in completely disbudded scions, nor in terminal parts of terminally disbudded scions, but do develop in the base of scions of which only the basal part has been disbudded.

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