STARCH IN APPLE TREES.

W. A. PRICE.

In the absence of reliable data and abundant literature upon the subject of starch storage and its changes throughout the year, I have undertaken experiments which I hope will shed further light upon the problem. The changes in the living tissues, the sap wood and particularly the bark, were found unexpectedly complicated. A few of the typical conditions may be given for which an explanation is not as yet attempted. The presence of starch in the non-living tissue, the heart wood, was studied in detail, believing the conditions found may have an important bearing in explaining the very ready decay of apple tree wood, in comparison with that of some other trees.

In case of the living tissue, sections about 20 mic. in thickness were made at intervals of ten days in dormant season, and four or five days during the growing season. The presence of starch was determined, in the usual way, by the iodin test. Each time, one-year old, or older, twigs were examined, both from the higher and lower portions of the crown of the tree; and beginning April 17th, the roots were examined.

This work was done at Ohio State University in the spring of 1914, under the general direction of Prof. Wendell Paddock, head of the Horticulture Department, and Mr. Forest B. H. Brown of the Botany Department.

The following typical conditions were found:

Date	Temperature		Age of Wood Yrs.	Pith	Xylem		Bark			
	Max. F.	Min. F.			Wood Par.	Ray	Ray	Bast Par.	Pri. Cortex	Phelloderm
Jan. 9	42	34	1-9	+	+	+	0	0	0	0
Mar. 9	32	19	1-9	+	+	+	+	+	+	+
Mar. 19	26	20	1-10	+	+	+	+	0	+	+
April 24	77	51	1-10	+	+	+	+	+	+	+
May 14	63	41	1-8	0	0	0	0	0	+	+

+ = starch present. 0 = starch absent.

May 14, clear; March 9, partly cloudy; other dates, cloudy.

The conditions found on January 9th seemed typical for most of the winter months up to March. The remaining four sections show some of the many changes that were found from that time to the unfolding of the leaves. On March 9th occurred the first notable changes. As shown in the table, starch now appears in the bark, which does not agree with the results obtained by Gourley, Bulletin 9, New Hampshire Agricultural Experiment Station, for the ray tissue of the bark appears generally to show starch from this time (March 9) on during the period of observation (June 4).

Buds began swelling March 9 and opened on April 24, when the leaves were unfolding. While the buds were not greatly swollen, a great deal of sap was present. Also the grains of starch were generally corroded in the pith, and, to a much less extent, in the xylem throughout the upper portion of the crown. Twigs on the lower part of the crown indicated less activity, showing scarcely any corroding of starch grains. The first corrosion occurred in the one-year-old wood in the upper portion of the crown. About two days later, the same changes appeared in the lower portion of the crown. The starch began disappearing in the wood parenchyma, then the rays, and finally the pith, in the order named.

As before mentioned, changes appear first in the one-year-old twigs, then later in the older portions of the branch, as shown in the following table, made from a fifteen-year-old branch on May 1st:

Date	Age Yrs.	Pith	Xylem		Bark
			Ray	Wood Par.	
May 1...	1	+	0	0	0
May 1...	2	+	+	0	0
May 1...	3	+	+	0	0
May 1...	4	+	+	+	0
May 1...	5	+	+	+	0
May 1...	6	+	+	+	0
May 1...	7	+	+	+	+
May 1...	8	+	+	+	+

Besides showing the order in which the tissues are emptied of starch, it also shows how the process is delayed with the age of the stem. Beyond the eighth year no change has taken place by May 12th. Starch has nearly disappeared from all tissues above ground, except the heart wood.

Thus far, the storage of starch in living branch wood tissues has been considered. For the sake of comparison, sections from the trunk of a tree, with apparently non-living heart wood at the center, were now made. During the last week in January a tree showing 54 annual rings was cut at a height of one foot from the ground, and a series of starch tests made from outer bark to pith along both radii of the diameter. Very little starch was found in the bark. The sapwood just beneath the bark contained a considerable quantity distributed in the wood parenchyma and medullary rays, but mostly in the rays. The amount diminished inward from the bark gradually to the 12th year, then suddenly, from which point no starch was regularly found in the wood parenchyma, except at certain intervals to be described later. From the 23rd year, the wood had the dark brown heart wood color; here starch still occurred in the ray cells, but intermingled with empty cells. At certain intervals, 23rd, 37th and 51st annual rings, occurred places where the storage tissues, both rays and wood parenchyma, were densely filled with starch, particularly in the summer wood portion of the ring. Such starch accumulations in the heart wood may possibly be explained on the assumption of "excess storage"; i. e., years when conditions were favorable for the production and storage of starch, followed by a fruitless, or partly fruitless, season. Inasmuch as fruit production is probably one of the principal sources of starch consumption in the tree, one can readily see that a condition of abundant supply would exist with little provision for an outlet, and hence account for the accumulation of starch in the heartwood. The fact that more or less starch is stored in the annual rings throughout the heartwood, and is not used from year to year, but simply remains in the heart wood intact during the life of the tree, suggests a reason for the decay of the trunk and the inner parts of the larger limbs of the apple tree. It is well known that starch is one of the best foods for the nutrition of fungi, and when once the spores get access to the stored starch in the heartwood, it is only a short time until the spread of the fungus

reaches other portions, causing decay of the plant tissues, and very soon the body of the tree becomes a shell. The sap wood remains actively engaged in the functions necessary to the life of the tree, and fungi do not so easily get hold. This gives us the shell condition of the apple tree, which is so common in old orchards where wounds to the tree are neglected, and incidentally, artificial roadways made to the heartwood of the tree for the access of fungi.

In summary, it may be stated that, during the dormant period, starch reserve is stored in the living cells of the pith, wood parenchyma, and medullary rays of the apple. With approach of spring, starch is found in the tissues of the bark, appearing first in the phelloderm and collenchyma.

As the leaves begin to appear, starch begins to disappear from the various tissues in order as follows: bark, wood parenchyma, rays, pith. It is used first from the youngest wood of the branches in the top of the tree, later, from the lower portions of the tree, and finally from the roots.

A portion of the starch reserve may never be used in the growth of the tree, but remains behind to be included in the heartwood where it remains indefinitely and renders the wood susceptible to decay.

Purdue University.