STARCH RESERVE IN RELATION TO THE PRODUCTION OF SUGAR, FLOWERS, LEAVES, AND SEED IN BIRCH AND MAPLE.

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American scientific literature is lacking in a standard treatment of subjects dealing with the stored reserve in our fruit and forest trees, such as have been made by Büsgen in his "Waldbäume," and in other still more recent German publications. The work of Jones and others of Vermont (Bull. 103, 1903) contains much information on the maples. But this work does not furnish the drawings essential to a clear presentation of starch storage, and the description is inadequate. Even in this bulletin, no attempt is made to show in what way the vast amount of potential energy represented in the stored starch is used, otherwise than in the production of sugar, while the authors themselves conclude that rarely is there used, in this way, more than 4% of the total starch stored in a tree.

This fact, together with the very conflicting statements made in the available published records, has led the writer to publish these few preliminary studies. The ease with which such studies may be carried on, together with their direct bearing upon many of the vital problems of forestry and various branches of agriculture, would suggest their general fitness to be included in the botany laboratory course, even in the high school possessed of only one microscope.

Data for the present paper were taken from selected trees of birch and maple growing on the Ohio State University campus. Particular attention was given to a sugar maple, Acer saccharum Marsh., north-west of the law building. From a 1-year twing of this tree, a cross-section 20 mic. in thickness was cut April 1, by means of a sliding microtome, stained one minute in iodine, and then mounted in glycerine. A camera drawing was made, Fig. 1, the magnification being shown by the accompanying scale. Similarly, a section was cut from a root 8 mm. in diameter, Fig. 2. The granules of starch have been indicated in solid black. In the stem the starch grains are shown in the medullary rays (u. m. and b. m.), wood parenchyma (w. p.), and in all the primary xylem tissues except the vessels. The wood fibres were empty in all the sections studied; but in the root, the wood fibres, as well as the wood parenchyma and medullary rays, are filled. Also, many of the tissues of the bark, both of stem and root, contain starch. Beginning with the first layer inside the cork, they are, in order, as follows: the periderm, collenchyma, thin walled parenchyma, bast parenchyma, and bast rays. The maple, however, contained less starch at this period in the bark tissues than the birch

and other starch trees examined. In the sections illustrated, it is apparent that more starch is stored in the root tissue than in the stem; but the relative volume of stem and root would have to be known, before it would be possible to determine whether a greater absolute volume of starch is stored below than above ground.

It is now the purpose to record, as far as possible, in what manner the starch thus stored is used. In this connection, there are at least five considerations: as, (1) the amount used when a tree is tapped, (2) the amount used when the flowers are formed, (3) when the leaves are formed, (4) when wood is formed, (5) when a heavy "seed year" occurs. Of these, seed production is to be given special attention, since the maple, in common with most of the Ohio forest trees, is known to have regularly recurring periods of heavy seed production. The particular tree chosen is a carpellate tree, and, from its numerous flower buds, it is predicted that the current year is to be a "seed year." (1) and (2) are now complete and it seems best to give results in this paper, rather than delay until all is finished.

To test the sugar production, the seven tree species tabulated below were tapped in a manner somewhat similar to the way the birch is tapped in Russia. Borings 1½ inches deep were made by a drill ⅛ inch in diameter, and a straw, cut from a thrifty stem of wheat, of a diameter to fit the hole snugly, was inserted far enough merely to penetrate the bark. One-pint Mason jars with water-proof card board caps, perforated to receive the straw, were suspended to collect the sap. 500 to 1000 grams of sap were collected from each tree, evaporated in a large porcelain evaporating dish in the laboratory, and the following percentages of sugar determined:

Species	Date	Per cent sugar in sap	Grams sap per hour	Grams sugar per hour
1. Acer nigrum Mx.....	April 6	2.7%	250 g.	6.7 g.
2. Acer saccharum Marsh....	April 9	2.4%	62 g.	1.5 g.
3. Acer platanoides L.....	April 9	2.2%	35 g.	.8 g.
4. Acer saccharinum L.....	April 7	2.1%	125 g.	2.6 g.
5. Acer negundo L.....	April 6	1.7%	500 g.	8.5 g.
6. Betula alba L.....	Mar. 31	1.2%	62 g.	.7 g.
7. Betula papyrifera Marsh.	April 4	1.1%	100 g.	1.1 g.

The birches produced a clear, amber colored, wax-like sugar, which does not granulate. The per cent is less than in any of the maples. In Russia, the birch is quite generally tapped. Sometimes this sap is fermented to make birch wine. Of the maples, Acernigrum Mx., the black maple, had the greatest concentration of sugar in the sap, which confirms the statement in Bull. 516, U. S. Dept. Ag., p. 8. But the box elder, Acer negundo, a

small tree on the south bank of "Mirror Lake," while producing a sap of lowest concentration, yielded more sugar per hour than any other of the maples. Under the varied conditions of the experiment, all maples produced a clear creamy white sugar in which little difference in taste was noticed, although the silver maple, No. 4, was in flower at the time. The average concentration of sugar in the sap for the maples was 2.2 %. These results, together with those of Professor Jones, make it probable that the Bonn Text Book is in error in rating the average % for the North American maple at ½ of 1%. The average yield of maple sugar per hour was 4 grams.

At the close of the sap run, April 10, there was almost no corrosion of the starch granules in any of the woody tissues of the sugar maple. There was little starch in any of the tissues of the bark of the young twigs; but starch was still abundant in the same tissues of the root. On April 24, the flowers had fairly opened, and were so numerous as to give the crown of the tree a general green color. Starch had been used from the branches examined, which showed less than 9 annual rings of wood.

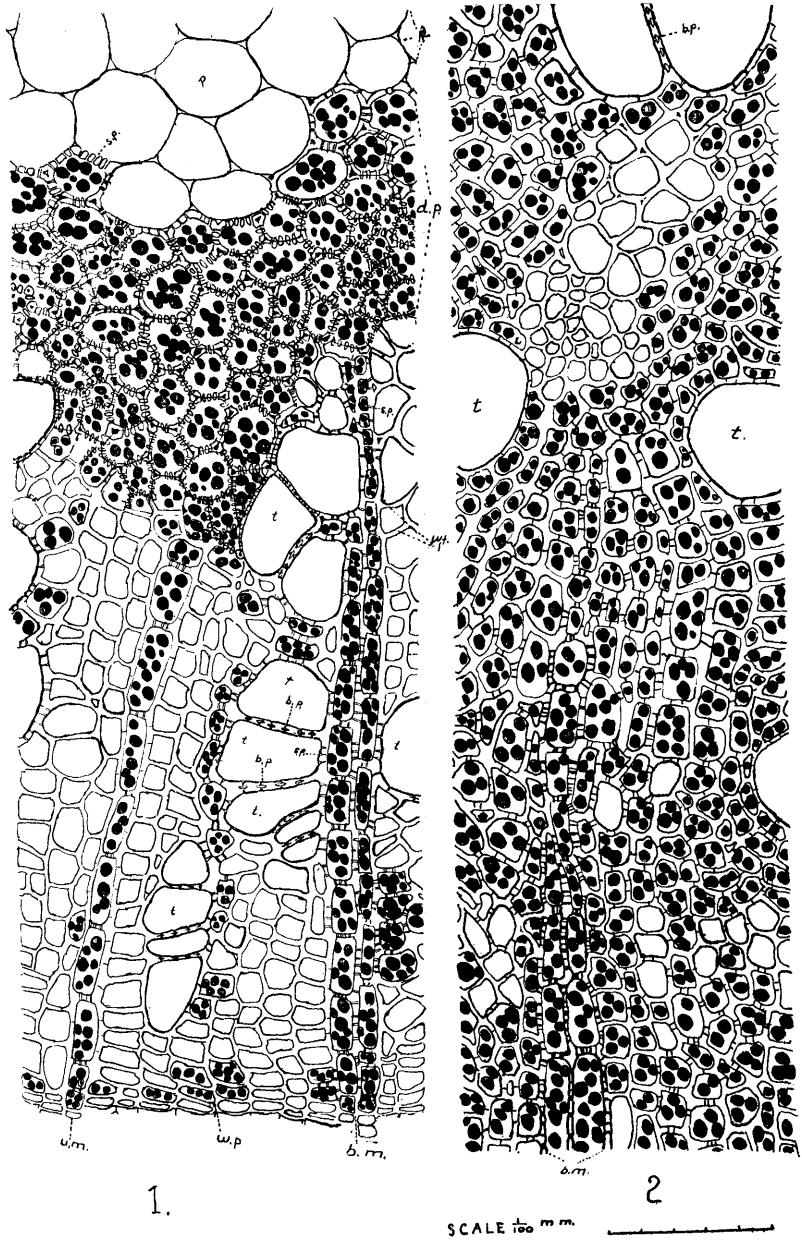
In summary, it may be stated that, previous to bud growth, little starch had been used, the most pronounced changes being confined to the bark of the stem. While buds were swelling, the starch was used from twigs showing less than 3 annual rings of wood. By the time flowers were fully formed, starch had been used from all portions of the stem showing less than 9 annual rings of wood. In other words, starch has been used first from the 1-year old twigs; then, from those portions of the branch showing two annual rings of wood; then, from portions showing 3 annual rings, and so on progressively down to that portion of the branch showing 10 years of wood. Beyond this, as in the root, no marked changes have occurred as yet.

I am indebeted to Mr. H. Udovitch, who has generously aided in collecting data in the flow of sap, and who has supplied the information concerning the use made of the birch in Russia.

EXPLANATION OF PLATE XV.

Figure 1. Cross-section of 1-year old twig.
Figure 2. Cross-section of root.

u. m. uniseriate medullary ray.
b. m. biseriate medullary ray.
t. trachea.
d. p. differentiated pith zone.
p. undifferentiated pith cell.
w. f. wood fibre.
w. p. wood parenchyma.
b. p. bordered pit in section.
s. p. simple pit in section.



Brown on "Starch Reserve."