A PRELIMINARY STUDY OF THE LENGTHS OF THE OPEN VESSELS IN THE BRANCHES OF THE AMERICAN ELM[1]

FRANKLIN G. LIMING

Results obtained from previous studies by the writer, using basic dyes and the spores of *Graphium ulmi* (the fungus causing the Dutch Elm Disease) in elm branches, and other workers, using mercury and various dyes in apple, oak and other woody stems, indicate that in a given species the length of the vessels in young stems is less than in older stems and that in stems of the same age there is a close correlation between the length of the vessels and the length of the stems in which they occur. As a preliminary study of the development of the water conducting system of the American elm (*Ulmus americana* L.) about 1,100 vessels in branches of different ages and lengths were measured to ascertain the relationship which exists between the length of the vessels and the age and length of the branches in which they were located.

The branches used in this study were taken from the upper part of the crowns of young elm trees during the month of February, 1932. The trees were about 11 m. high and about 15 cm. in diameter 1 m. from the ground. Only those branches which had made what appeared to be a "normal" growth in length during the last four years were used. Owing to the fact that the length of the terminal growth on the same branch varies from year to year and on different branches within the same year the length of the portion of the branch to be used was determined by yearly segments and parts of yearly segments rather than by definite fixed lengths.

In making the determinations the basal ends of branches of the desired age were cut square across with a sharp knife and connected to the lower end of a mercury column by means of a piece of "high pressure" rubber tubing. An arbitrary height of 120 cm. of mercury was chosen as a source of pressure. Mercury under this pressure will pass through any unobstructed opening over 1.3 μ in diameter with which it comes in contact. The lumina of the water conducting vessels in elm branches are

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well over 1.3 μ in diameter. With the cut end of the branch in contact with the mercury and the rest of the branch held in a horizontal position, pieces about 0.5 cm. long were cut successively from the unattached end of the branch until the mercury was observed to pass through the remaining portion of the branch in one vessel. The high surface tension of the mercury causes it to take the form of small spherical droplets as it first emerges from the branch, thus making its presence and exact location easily determined. The fact that the mercury passes through the branch indicates that there is one opening 1.3 μ or more in diameter extending the entire length of the remaining portion of the branch. Since the mercury does not pass through the branch before the last piece is cut off the opening must terminate in that section. Therefore the vessel either terminates at an end wall in that section or is plugged by some mechanical obstruction such as tyloses, gums, etc. Just how far the vessel or opening being measured extends below the point at which the mercury was attached can not be determined. Thus it is evident that the measurements obtained by the above method do not necessarily represent the full length of the vessel but only the length of the branch from the point of attachment through which there is a continuous opening 1.3 μ or more in diameter. The term "open vessel" as used in this paper refers to such openings. After the longest open vessel in a branch was measured the length of other open vessels in the same branch was ascertained by cutting off additional pieces, watching for the appearance of other mercury droplets, and then measuring the length of the portion of the branch through which the mercury passed in the other vessels.

The longest 15 vessels in all the branches were located in the outside annual ring. When the branches were cut back to such a length that the mercury passed through them in the vessels in the inner annual rings the amount of mercury coming through the open vessels in the outer annual ring was so great that it was impossible to determine the exact number of vessels through which the mercury was passing in the inner annual rings. The passage of mercury through the vessels in the outer ring was avoided by disconnecting each branch from the mercury column after the vessels in the outer ring had been measured and carefully removing the wood of the outer annual ring of each branch at the basal end so that when the branch was

again connected to the mercury column the vessels in the outer annual ring were not in contact with the mercury. With the branch connected in this way the length of the open vessels in the inner annual rings was measured. In no instance was the mercury observed to pass from the vessels in any one annual ring to the vessels in any adjacent annual ring. This indicates that there were no openings 1.3 μ or more in diameter connecting the open vessels in any two annual rings.

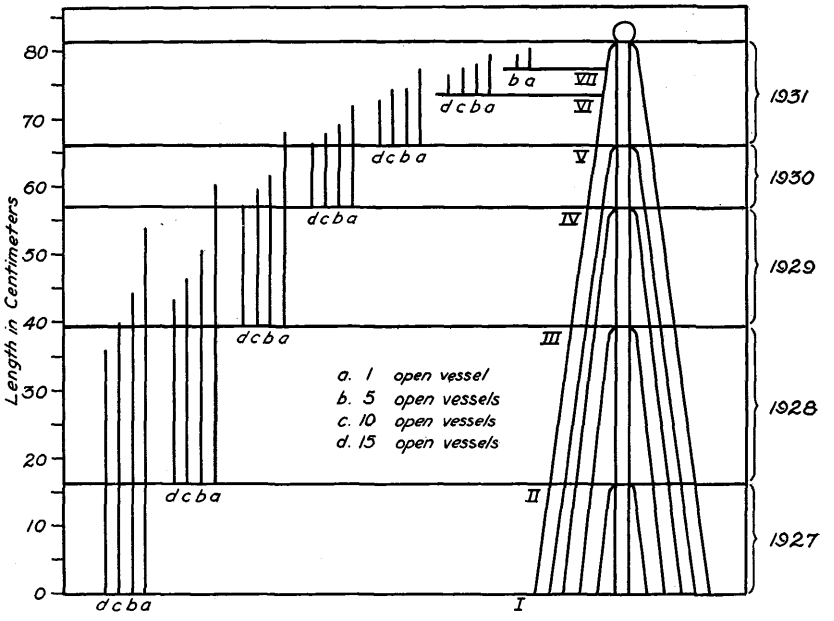

FIG. 1. The average length of the last five yearly segments of the branches of American elm and the average length of the longest portion of the branches through which mercury passed in 1, 5, 10 and 15 open vessels in the spring wood of the 1931 annual ring from the points I, II, III, IV, V, VI and VII.

The above method is suitable only for branches less than 3 cm. in diameter. The larger branches used in this study were connected to the mercury column with an "injection jet" designed by The Davey Tree Expert Co. In this way the mercury is introduced into the branch through a hole bored into the side of the branch instead of at the basal end as in the smaller branches. Instead of the small 0.5 cm. pieces, sections 5 to 10 cm. long were cut from the end of each branch until the mercury passed through the remaining portion of the branch.

Figure 1 represents diagramatically the average length of

the last five yearly segments of the branches used and the average length of the measured open vessels in the spring wood of the 1931 annual ring in these segments. Mercury was applied at the points I, II, III, IV, V, VI, and VII in the various branches and forced towards the terminal end of each branch. The length of the portion of the branch and the number of vessels in which mercury would pass through the branch was found to be the same regardless of which end of the branches was attached to the mercury. The lines a, b, c, and d represent the average length of the branches through which the mercury passed in 1, 5, 10, and 15 vessels respectively from the point of attachment.

The open vessels measured in this study ranged in length from 0.5 cm. to 5.5 m. The shortest open vessels measured were located just below the terminal buds and the longest open vessels were located in the spring wood of the 1931 annual ring in the lower part of the trunks.

There is a very definite and consistent correlation between the length of the open vessels in the spring wood of the 1931 annual ring and the length and age of the branch in which they are located. In general the length of the longest portion of the branch having five open vessels extending through it is about 55% of the total length of the branch. The length of the open vessels is more closely correlated with the length of the branch, and with the age of the branch in so far as it affects the length of the branch, than with the age alone. For example, the open vessels in branches of the same age and length were found to be about the same length while those in other branches of twice the age and double the length were found to be about twice as long. However, if the branches were all the same age and some of them were twice as long as the others the vessels in the longer branches were not twice as long as those in the shorter branches but only about 90% to 95% longer. Also, if the branches were all the same length and some of them were one year older than the others the vessels in the older branches were found to be from 5% to 10% longer than the vessels in the younger branches.

In the inner annual rings, the vessels or openings through which the mercury passed were limited largely to the summer wood of each ring and were only from 5% to 10% as long as those in the spring wood of the outside ring in the corresponding segment of the same branch. Microscopic examination showed

that there were many tyloses present in the spring vessels in these inner annual rings. The actual length of the vessels in the spring wood of the inner annual rings may be the same as those in the outside ring of the corresponding segment, but the passage of mercury was prevented in some way, probably by the presence of tyloses, gums or other mechanical obstructions. The fact that mercury fails to flow for more than short distances through the vessels of these inner annual rings does not, of course, necessarily mean that the movement of water through such vessels is similarly restricted. A more detailed study dealing with the structure and time of formation of these obstructions is now in progress.

SUMMARY

1. The length of 1,100 open vessels in American elm branches of different lengths and ages was ascertained by forcing mercury through the branches under a pressure of 120 cm. of mercury.

2. There was found to be a close correlation between the lengths of the open vessels in the spring wood of the 1931 annual ring and the lengths of the branches in which they were located. The length of the longest five open vessels extending through the branches, from any point on the branch, towards the terminal end was found to be about 55% of the distance of that point from the terminal end of the branch.

3. There was also a close correlation between the age of the branches and the length of the vessels in them. This correlation was found to be largely due, not directly to age alone, but to the increase in length of the branches resulting from the increase in the age of the branches.

4. There was no evidence that the mercury passed from the vessels in any one annual ring to the vessels in any other annual ring.

5. In the inner annual rings, the vessels or openings through which the mercury passed were limited largely to the summer wood of each ring and were only from 5% to 10% as long as those in the corresponding segment in the 1931 annual ring.

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