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Short Communication

Retention of Calcium-45 by Dogwood Trees[1]

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Retention of Calcium-45 by Dogwood Trees[1]

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The relatively slow movement of calcium through plants and its relative immobility within plants, compared with other elements, is well documented (2, 3, 5, 6, 14, 15, 19, 20). However, evidence that calcium is redistributed within plants is increasing (4, 7-13). This communication reports the amounts of ^{45}Ca available for transport from woody tissue to foliage during three growing seasons after stem inoculation of dogwood (*Cornus florida* L.) trees.

Twelve trees were inoculated with ^{45}Ca on May 4, 1966, by placing water in troughs around the tree stem, 1 dm above the ground, making chisel incisions into xylem under the water surface, and adding the radiocalcium while water was entering the transpiration stream. The amount of ^{45}Ca per tree, from 0.67 to 2.51 mc, was proportional to estimated tree weight. Eight of the trees were harvested in November, 1966, after leaf abscission, to determine the distribution of ^{45}Ca in woody tissues. Two of the four remaining trees were harvested for analysis in November, 1967, and the last two in November, 1968. A sample of 50 leaves collected monthly from each of the trees present during the three growing seasons was analyzed for ^{45}Ca. Removal of all leaves under the tagged trees after leaf abscission in 1966 and 1967 ensured that the ^{45}Ca released from decomposing litter would not be available for root absorption, thereby confounding the distribution of radiocalcium. Samples were oven-dried at 105 C, weighed, and ashed overnight in a muffle furnace at 575 C. The ash was dissolved in 4 N HCl and diluted to volume. A 4-ml portion of this solution was evaporated on planchets and counted with a Beckman Instruments, Inc., Widebeta II planchet counting system for 20 min or 10^6 counts. All counting data were corrected for background radioactivity in control material. Detailed methods and results for the first growing season are presented elsewhere with other information on the calcium relationships of dogwood trees (17).

The ranges in pertinent values for the 12 trees (with the mean shown in parentheses) are: age, 13 to 16 years (15 years); diameter at ground level, 4.4 to 7.1 cm (5.7 cm); diameter 1 m above ground, 2.6 to 4.7 cm (3.6 cm); height, 3.2 to 5.7 m (4.6 m); ovendry weight of roots, 320 to 1430 g (780 g); number of leaves in September, 2420 to 9230 (4910); maximum ovendry weight of foliage attained in early September, 350 to 1880 g (750 g); and ovendry weight of above ground woody tissues, 1760 to 6440 g (3470 g).

Foliage of the 12 trees contained 73% ± 6 (SE) of the inoculum 1 month after inoculation. Losses of ^{45}Ca from these trees during the first growing season, expressed as a percentage of inoculum remaining after radioactive decay, were by leaf fall 64%, foliar leaching 6%, insect damage 3%, and stem flow (precipitation channeled down branches and stem to the ground) $\ll$1%. In late September of the first growing season, newly formed leaves and samples of solution extracted from the transpiration stream in twigs contained ^{45}Ca. Presence of radiocalcium in foliage collected from all 4 trees the following April confirmed that ^{45}Ca was still available for translocation to leaves. Loss of ^{45}Ca by leaf fall averaged 24% ± 3 of inoculum remaining after radioactive decay in 1967 and 7% ± 4 for the last 2 trees in 1968. These losses are equivalent to 81% ± 4 and 84% ± 3, respectively, of the ^{45}Ca remaining in the trees after losses of radiocalcium during previous seasons.

Only one tree produced inflorescences during the 3 years. Thirteen inflorescence buds collected when one of the last two trees was harvested in 1967 weighed a total of 0.70 g ovendry. The ^{45}Ca concentration, 3230 dpm/g ovendry, surpassed that in foliage at the time of abscission by a factor of 1.4. Stable calcium concentration in inflorescence buds at the end of the growing season, 3.6% of ovendry weight, exceeded that in leaves, 2.8% (17). New branches produced in 1968 also contained radiocalcium. The mean ^{45}Ca concentrations in five 1-g ovendry samples of current annual growth including buds, 2290 dpm/g from one tree and 1420 dpm/g from the other, were 0.88 and 0.75 times those in foliage at time of abscission.

Six months after inoculation, the branches contained 57% ± 3 of the inoculum remaining in woody tissues of the eight harvested trees, with 40% ± 3 in the stem and 3% ± 1 in roots. The contribution of roots to total ^{45}Ca in woody tissues increased to 5% in 1967 and to 9% in 1968. In all 12 trees the ^{45}Ca content of roots > 2 cm in diameter exceeded that in roots < 2 cm in diameter by a factor of at least 4, both in total amount and in concentration (dpm/g).

Ten stem segments about 4 cm in length from each harvested tree were divided into wood and bark for separate ^{45}Ca analyses; none of these samples was collected within 50 cm of the site of inoculation. The contribution of bark to sample weight ranged between 14 and 19%. Contribution of bark to total ^{45}Ca in the segment, however, averaged 93% ± 2 in 1966, 90% ± 2 in 1967, and 91% ± 3 in 1968. Similarly, analyses of bark and wood from 10 branch samples about 1 cm in diameter and 10 cm in length from the last two harvested trees showed that bark contributed 19% ± 1 of weight but 89% ± 2 of total radiocalcium in the samples. The stable calcium concentration of stem bark averaged 4.0% of ovendry weight, but that of xylem was only 0.12%; bark accounted for 18% of stem weight but 88% of the stable calcium in the stem (17). Calcium is transferred from xylem to phloem, where it is apparently retained (6, 20). Bark functions as a calcium sink, although sloughing of bark causes the calcium retained in it to be recycled more rapidly than that retained in xylem.

Xylem samples collected from the stem at four different heights above the site of inoculation on each of the 12 trees

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were air-dried, ground in a Wiley Mill to pass a 0.5-mm mesh screen, and thoroughly mixed to form one composite sample for each tree. A 10-g portion of each composite sample was placed in a cylinder with a sintered glass filter at one end; the wood formed a column 2 cm in diameter and 6 cm in height. Ten 25-ml fractions of distilled water at 24 C eluted the ^{45}Ca; each fraction was analyzed separately for radiocalcium. The pH of eluate averaged 5.3. After the 250 ml of distilled water passed through the column, the wood was removed and analyzed to determine how much ^{45}Ca remained. After the first growing season water removed 12% ± 1 of the ^{45}Ca in the eight xylem samples. This value increased to 28% ± 2 after the second growing season and to 46% ± 2 after the third. In all 12 cases, the first 10-ml fraction removed about 90% of the total ^{45}Ca eluted, and the first three fractions removed over 99%. Similar leaching of four bark samples after the third growing season showed that only 7% ± 1 of the ^{45}Ca was water-soluble. The first 10-ml fraction of eluate from the bark samples contained 48% of the total ^{45}Ca eluted; radioactivity in the seventh fraction from all four columns of bark did not exceed that from control columns.

The results reported here do not conflict with the hypothesis that xylem functions as an ion exchange column for calcium (1, 16). The ^{45}Ca contained in foliage during the second and third growing seasons had to be transported in xylem when growth commenced in the spring, 12 and 24 months after stem inoculation. Calcium is not returned from foliage to woody tissues of dogwoods at the end of the growing season (17). Upward movement of the ^{45}Ca by exchange reactions in the stem and branches can account for the supply of radiocalcium. The much higher water solubility of ^{45}Ca in xylem and the known immobility of calcium in phloem (2, 20) indicate that xylem provided the radiocalcium for translocation to foliage. The relatively constant percentage contribution of xylem to total stem radiocalcium during successive seasons suggests replacement of ^{45}Ca from lower levels in the stem. The change in radiocalcium content with increasing height in the stem, as shown in another study (16), was not determined because branches within 1 m above the site of inoculation on all trees undoubtedly influenced the distribution of ^{45}Ca.

Any discussion of calcium movement in plants should consider semantics as well as chemistry. The implications of such words in the literature as "deposition," "immobilization," "localization," and "redistribution" are not always clear when used to describe calcium behavior. The probability of subsequent movement of a calcium ion is quite different, for example, when it is immobilized on an exchange site, where it can be replaced and thus re-enter the solution phase, than when it is immobilized in a calcium oxalate crystal or as a constituent of a cell wall.

The results of most studies of calcium mobility in plants can be explained by polarity of calcium movement (18) and by the influence of ion exchange on the translocation of calcium by the transpiration stream; these phenomena are particularly applicable to the interpretation of results from studies in which calcium is not removed from the solution phase as a result of metabolic processes.

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