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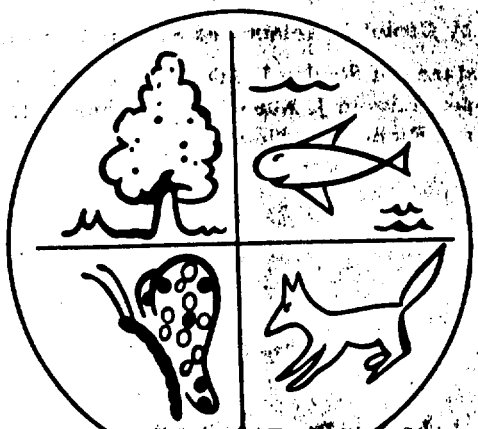

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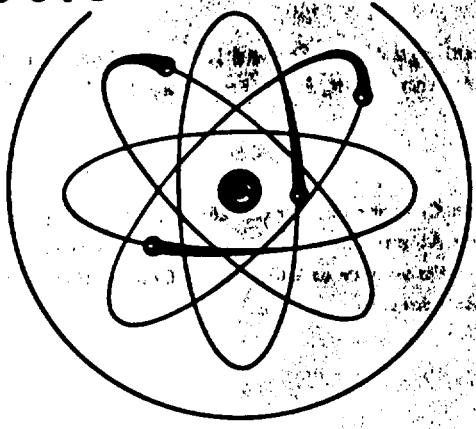

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CYCLING OF ^{45}Ca BY DOGWOOD TREES

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Abstract. Twelve flowering dogwood (*Cornus florida* L.) trees, stem-inoculated with ^{45}Ca in early May, retained only 27% ± 3 of inoculum in woody tissues (stem 11, branches 15, roots 1) at the end of the growing season. Losses (as percentage of inoculum) were by leaf fall (64), foliar leaching (6), stemflow (<<1), and insect damage (3). Rapid turnover of inoculated calcium (73% ± 3) by these trees within a single growing season adds to the evidence that this species is a nutritionally beneficial component of forest communities.

Introduction

Flowering dogwood (*Cornus florida* L.) has been cited as a nutritionally beneficial understory tree due to accumulation of calcium in its leaves (Coile 1940, Metz 1952), thus keeping this essential element in circulation in upper soil layers. This paper describes one experiment in a comprehensive investigation of the accumulation and cycling of calcium by this species, the detailed results of which will be presented later. The experiment was performed to elucidate the movement of calcium in the tree-soil system during a single growing season. Although stable calcium analyses answered several questions concerning the function of dogwood as a calcium "pump," fulfillment of this objective required use of radiocalcium.

Methods and Materials

Plant and litter material was oven-dried at 105 C for 48 hours and ashed overnight in a muffle furnace at 575 C. Ashed samples were dissolved in 4 *N* HCl, filtered, and diluted to known volume. Shaking soil samples overnight in an excess of 1 *N* HCl extracted radiocalcium. A 4-ml aliquot of sample solution was slowly evaporated in a planchet and counted with a Beckman Instruments, Inc., Widebeta II planchet counting system for 20 minutes or 10^6 counts. Counting data were corrected for machine efficiency, background radioactivity in control samples, and radiological decay. Average values are presented as the mean plus or minus one standard error of the mean.

Twelve dogwood trees (from 4.4 to 7.1 cm in diameter at ground level and from 3.3 to 5.2 m in height) in the understory of a 19-year-old loblolly pine (*Pinus taeda* L.) plantation in Roane County, Tennessee, were selected for inoculation. Inoculum (0.67 to 2.51 millicuries of $^{45}CaCl_2$ in solution at pH 5 with specific activity of >15 mCi/g of Ca) was proportional to estimated tree weight (1 mCi per 2500 g oven-dry). A regression equation based on data from 20 trees provided estimates of tree weight (roots + top without foliage) as a function of tree diameter and height.

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[1]Research performed while the author was an Oak Ridge Graduate Fellow from the University of Minnesota under appointment from Oak Ridge Associated Universities.

[2]Operated for the U.S. Atomic Energy Commission by Union Carbide Corporation.

1024928

Trees were inoculated on 4 May 1966 by placing water in troughs (1 dm above ground) around the tree stem, making chisel cuts into xylem at 1 cm intervals around the stem circumference, and adding the inoculum while water entered the transpiration stream. All troughs emptied once within 20 minutes; they were refilled with water three times, removed after all water entered the tree, and soaked overnight in 1 *N* HCl to estimate ^{45}Ca retention on troughs.

Three polyethylene rain gauges placed under each tagged tree and a control tree were rerandomized several times during the experiment. Troughs, 3 dm above the ground, on four tagged trees and the control tree diverted stemflow into polyethylene bottles connected with plastic tubing to the troughs. Throughfall and steamflow were sampled after every period of continuous precipitation. Measurement of ground area under crowns of tagged dogwoods permitted estimation of total quantity of ^{45}Ca which reached the forest floor.

Monthly samples of 50 leaves from each inoculated tree (two leaves from each of 25 branches, representing the entire crown) provided data on ^{45}Ca content of foliage. A regression equation which related number of leaves to branch diameter allowed estimation of total number of leaves on eight of the dogwoods harvested at the end of the growing season.

Insect damage was estimated on 400 leaves collected on each leaf-sampling date from adjacent untagged trees. A regression equation provided estimates of leaf area based on the product of leaf length and width. Area of holes in leaves, almost exclusively in intervein area, was measured with a transparent grid (1 mm^2 squares) laid on contact photographic prints of the sample leaves. Known distribution of ^{45}Ca in these leaves (Thomas 1968) permitted estimation of losses due to insects.

Calcium-45 determinations for each of four woody-tissue components (stem, branches, roots >4 cm diameter, roots <4 cm diameter) of eight tagged trees harvested after leaf abscission provided additional data on radiocalcium turnover by dogwoods.

Results and Discussion

Essentially all of the inoculum entered the trees (troughs retained only 0.1% ± 0.02 of the ^{45}Ca).

On 5 June, one month after inoculation, foliage contained 73% ± 6 of total inoculum. Calcium-45 concentrations steadily decreased during the remainder of the season due to radiological decay, foliar leaching, and leaf fall. Radiocalcium lost from trees by leaf fall equalled 64% ± 1 of total inoculum.

Rapid uptake of inoculum and polarity of calcium movement in plants, which limits calcium to acropetal movement (Tukey, Wittwer, and Bukovac 1962), accounted for the large percentage of total ^{45}Ca which reached foliage. Because calcium is not returned to woody tissue prior to leaf abscission, as are several other elements (Stenlid 1958), a large fraction of foliar ^{45}Ca was lost from these trees at the end of the growing season.

Insects removed 1.8% of total foliar area during the growing season, a value somewhat lower than expected (Bray 1964). This loss represented 3% of inoculum.

All samples of throughfall and stemflow, collected 15 times during the experiment, contained ^{45}Ca, with throughfall accounting for 6% ± 1 of inoculum. Stemflow, which contributed only 0.20% ± 0.01 to total volume of water and 0.17% ± 0.02 to total ^{45}Ca that penetrated the tree canopy, accounted for only 0.01% ± 0.01 of total inoculum. The appreciable role of precipitation in removal of calcium from foliage is to be expected (Attiwill 1966), while the role of stemflow will normally be minimal due to its small contribution to total precipitation reaching the forest floor under trees (Helvey and Patric 1965).

Analysis of two litter samples (exclusive of fallen dogwood leaves) and the underlying mineral soil to a depth of 6 cm (soil at greater depths did not contain ^{45}Ca) under each of the 12 tagged trees on 12 October showed that 88% ± 1 of the recovered ^{45}Ca was in litter. Although additional precipitation will leach more ^{45}Ca into soil, retention of the divalent ^{45}Ca ions on exchange sites in the pine litter will undoubtedly retard this transfer. Radiocalcium found in above-

1024929

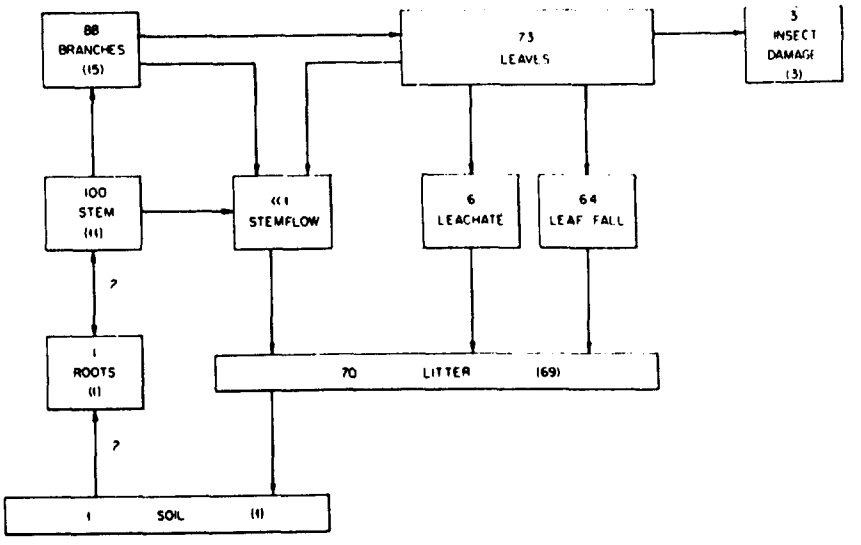

Fig. 1. Distribution of ^{45}Ca after stem-inoculation of dogwood trees. Numbers not in parentheses represent maximum percentages of inoculum in components of the tree-soil system during the growing season. Numbers in parentheses are percentages of inoculum found after leaf abscission. Trees were tagged on 4 May and harvested on 4 November 1966.

ground portions of ground vegetation (*Campsis radicans*, *Lonicera japonica*, *Smilax* sp.), apparently a result of foliar absorption of ^{45}Ca leached from dogwood foliage, represented a negligible amount of the inoculum because of the paucity of ground vegetation under the trees.

Aboveground parts of the harvested trees contained 97% ± 2 of the ^{45}Ca found in non-foliar tissues. Xylem accounted for 93% ± 1 of radiocalcium in the stem. Stem and branches retained 26% of inoculum, most of which was probably bound on exchange sites in xylem and bark (Bell and Biddulph 1963, Thomas 1967). It is not clear how ^{45}Ca entered roots, but it apparently descended from the stem because the amount of radiocalcium in roots >4 cm diameter exceeded that in roots <4 cm diameter by a factor of 4.4 and since there was only a small quantity of ^{45}Ca available for root-absorption in soil. This does not refute the concept of polarity of calcium movement in plants because trees were inoculated so close to roots that some radiocalcium could have diffused downward in bark (as opposed to translocation).

Sample data and known pathways of calcium transfer were used to prepare a diagrammatic summary of the results (Fig. 1). Estimated amount of ^{45}Ca accounted for at the end of the experiment (106% ± 5 of inoculum remaining after physical decay) is well within limits of sampling error for a weak beta emitter in a tree-soil system for six months.

Taylor (1966) predicted, based on interphase chromosome volume, that dogwood meristems were most sensitive to radiation in June, the month they probably contained the greatest amount of ^{45}Ca (0.20 ± 0.04 μCi/g on 5 June). Apical meristems received an estimated dose of 74 ± 15 rads during the entire experiment, as estimated with equation 92a in Loevinger, Holt, and Hine (1956), corrected for beta particle energy not absorbed by cylindrical tissues (Parmley, Jenson, and Mays 1962). The dose rate (<1 rad/day) is about two orders of magnitude less than that required to cause slight growth inhibition in a species with the seasonal interphase chromosome volume of dogwood (Sparrow 1965).

Rapid turnover of inoculated calcium by these trees is further evidence that dogwoods are beneficial in keeping calcium in circulation in the biologically active upper layers of soil. Although this study emphasizes nutritional aspects of calcium cycling, knowledge of ^{45}Ca circulation may also be of interest (1) after nuclear detonations (James and Fleming 1966), (2) since calcium and strontium behave similarly in forests (Aleksakhin and Ravikovich 1966), and (3) in forest fertilization research (Mustanoja and Leaf 1965).

1024930

Literature Cited

Aleksakhin, R. M., and M. M. Ravikovich. 1966. Certain patterns in the behavior of alkaline earth elements (Ca, Mg, Sr) in forest biogeocenosis. Soviet Soil Sci. 1966: 414–421.

Attiwill, P. M. 1966. The chemical composition of rainwater in relation to cycling of nutrients in mature eucalyptus forest. Plant and Soil 24: 390–406.

Bell, C. W., and O. Biddulph. 1963. Translocation of calcium. Exchange versus mass flow. Plant Physiol. 38: 610–614.

Bray, J. R. 1964. Primary consumption in three forest canopies. Ecology 45: 165–167.

Coile, T. S. 1940. Soil changes associated with loblolly pine succession on abandoned agricultural land of the Piedmont Plateau. Duke Univ. School Forestry Bull. 5. 85 pp.

Helvey, J. D., and J. H. Patric. 1965. Canopy and litter interception of rainfall by hardwoods of eastern United States. Water Resources Res. 1: 193–206.

James, R. A., and E. H. Fleming, Jr. 1966. Relative significance index of radionuclides for canal studies. UCRL-50050-1. 10 pp.

Loevinger, R., J. G. Holt, and G. J. Hine. 1956. Internally administered radioisotopes. pp. 801–873 in: G. J. Hine and G. L. Brownell (Eds.). Radiation Dosimetry. Academic Press, New York.

Metz, L. J. 1952. Weight and nitrogen and calcium content of the annual litter fall of forests in the South Carolina Piedmont. Soil Sci. Soc. Amer. Proc. 16: 38–41.

Mustanoja, K. J., and A. L. Leaf. 1965. Forest fertilization research, 1957–1964. Bot. Rev. 31: 151–246.

Parmley, W. W., J. B. Jenson, and C. W. Mays. 1962. Skeletal self-absorption of beta-particle energy. pp. 437–451 in: T. F. Daugherty, W. S. S. Lee, C. W. Mays, and Betsy J. Stover (Eds.). Some Aspects of Internal Irradiation. Pergamon Press, New York.

Sparrow, A. H. 1965. Comparisons of the tolerances of higher plant species to acute and chronic exposures of ionizing radiation. Jap. J. Genet. 40 (Suppl.): 12–37.

Stenlid, G. 1958. Salt losses and redistribution of salts in higher plants. Encycl. Plant Physiol. 4: 615–637.

Taylor, F. G., Jr. 1966. Predicted seasonal radiosensitivity of southeastern tree species. Radiat. Bot. 6: 307–311.

Thomas, W. A. 1967. Dye and calcium ascent in dogwood trees. Plant Physiol. 42: 1800–1802.

Thomas, W. A. 1968. Calcium distribution in leaves: autoradiography versus chemical analysis. Int. J. Appl. Radiat. Isotopes 19 (in press).

Tukey, H. B., S. H. Wittwer, and M. J. Bukovac. 1962. The uptake and loss of materials by leaves and other above-ground plant parts with special reference to plant nutrition. Agrochimica 7: 1–28.

1024931