Influence of Blister Rust on Inorganic Solute Concentrations in Western White Pine

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ABSTRACT

In needle tissue of western white pine infected with *Cronartium ribicola*, N, K, and Ca were less and P, Mg, and Na were greater than in noninfected trees. Cankered tissue showed greater concentrations of N, K, and P than in either rust-free bark or bark from healthy trees. In contrast, Ca levels in infected bark were lower than in healthy or rust-free bark and lowest in sporulating canker tissue. Concentration of Mg varied in the following ascending order: diseased tree bark, periphery of canker, healthy tree bark, and sporulating canker tissue. The data support the hypothesis that cankers are metabolic sinks and that localized infection affects mineral distribution in the total tree.

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Additional key words: Pinus monticola, obligate parasitism, disease physiology, metabolite accumulation.

An obligate plant parasite, when integrating with its host's metabolism, alters the normal distribution of host solutes (7, 8). Metabolically important solutes (metabolic sinks) and dry weight increase within the invading organism's field of dominance (1, 5, 10, 13, 15, 17, 20). Such metabolic sinks include the fungus itself and the host tissue immediately adjacent to infection sites. Other parts of the plant supply the solutes in amounts adequate for fungus growth and sporulation. Pathogen-induced solute accumulations occur in annual plants at infection sites and in organs heavily infected with fungal mycelia (7, 18).

The literature offers little information on the effects of an obligate parasite on translocation and accumulation of inorganic solutes in perennial hosts. This study was undertaken to determine pathogen-induced differences in the solute concentrations within a perennial host. Such information could be useful in two areas of our over-all blister rust research program: remote sensing via aerial photography, and translocation of fungicides to infection sites.

MATERIALS AND METHODS.—Five trees, each having at least one canker girdling 50% of the bole circumference, and five trees, each free of infection by the blister rust fungus (*Cronartium ribicola* J. C. Fisch. ex Rabenh.), were selected from a 14- to 15-year-old western white pine (*Pinus monticola* Dougl.) stand in the East Fork drainage of the Potlatch River, Bovill, Idaho. Trees were sampled in August 1967; during the preceding 7 weeks, temperatures ranged from 90 to 103 F (32.2 C-39.5 C), 30 days were 90 F or above, and no precipitation was recorded.

Samples collected from each infected tree included noninfected bark one internode above the canker at the yellow nonsporulating margin of the canker, and bark from sporulating areas bordered by the yellow margin. Samples collected from each healthy tree included composite branch bark from the middle and lower crown and bole bark at the same aboveground height as canker samples. Two classes of needles, current year and 1 year old and older, were collected randomly from the top, middle, and lower crown of each healthy and diseased tree.

All samples were oven-dried in screw-cap bottles for 96 hr at 105 C. Bottles were capped before samples cooled. Then, a 1-g portion of each was pulverized and transferred quantitatively to 100-ml digestion vessels.

Nitrogen (N) concentrations were measured by the Kjeldahl method (4, p. 99-100), sodium (Na) and potassium (K) by flame photometry, and calcium (Ca) and magnesium (Mg) by atomic absorption instrumentation.

Phosphorus was assayed by comparing molybdate chromophore concentrations (11, 19) developed in clear perchloric acid ($HC1O_4$)-sulfuric acid (H_2SO_4) digests (3) of the oven-dried samples, and in dilutions of stock silver phosphate and ammonium phosphate solutions (0.1 g phosphorus/ml).

Sodium, K, Ca, and Mg determinations were made in clear solutions of oven-dried samples digested in a solution of water, concentrated H_2SO_4, and 70-72% $HC1O_4$ (1:1:2). Perchloric acid digests containing 0.1 N $HC1O_4$ and 500 ppm strontium corrected the slight depression in Ca determinations (2, 6); so these were used in preference to HNO_3 digests which depressed Ca measurements 21-25%. Heating was controlled to digest samples rapidly. When the digests cleared, 2 ml of 70-72% $HC1O_4$ were added and the solution was boiled 10 min. This step was repeated and the solution allowed to cool before dilution to the proper concentration for assays.

RESULTS.—*Bole bark.*—Concentrations of N and K in all bole canker tissues were at least 10 times greater than concentrations of other solutes. Nitrogen (the solute most highly concentrated in bole tissues), K, Mg, and P were similarly distributed. All four cations were more abundant in infected than in noninfected tissue. Moreover, their concentrations increased toward canker centers; levels in yellow margin and in sporulating tissues exceeded those in noninfected tissue by 100-130% and 140-200%, respectively.

Sodium, also more concentrated in infected than

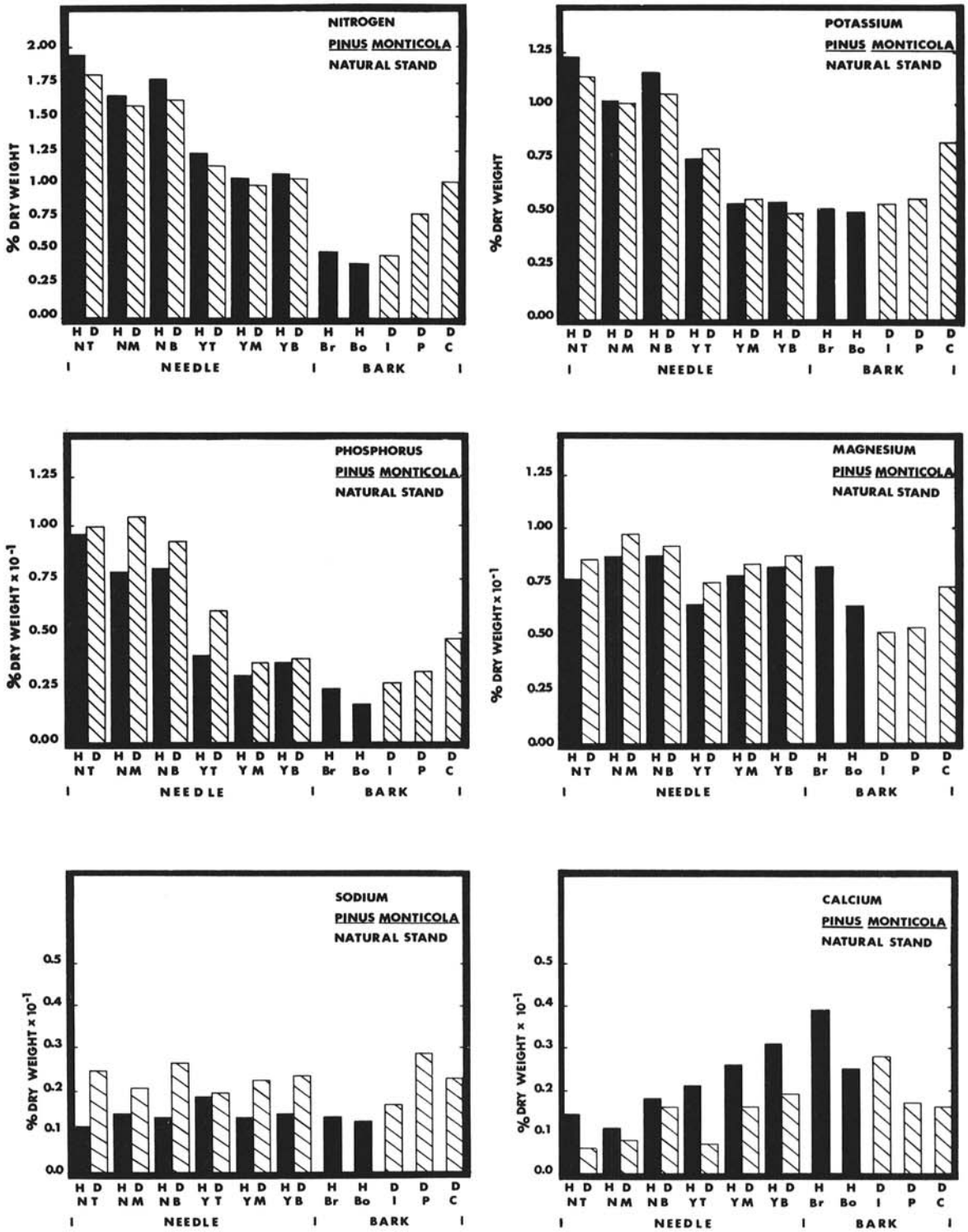

Fig. 1. Average concentration of solutes in blister rust-infected and noninfected host tissues of five western white pine trees and in tissues of five healthy western white pine trees. H = rust-free trees (healthy); D = rust-diseased trees; NT = needles, new growth, top crown; NM = needles, new growth, midcrown; NB = needles, new growth, bottom crown; YT = needles, 1-year-old, top crown; YM = needles, 1-year-old, midcrown; YB = needles, 1-year-old bottom crown; Br = branch bark; Bo = bole (trunk) bark; I = tissue one internode from the canker; P = periphery of the canker (yellow margin); C = canker center (sporulating area).

in noninfected tissues, reached its highest level in nonsporulating tissue (Fig. 1). Concentrations in sporulating tissue and yellow margin tissue increased 140% and 180%, respectively, over those in noninfected tissue.

Calcium was consistently lower (57-60%) in infected tissues than in all noninfected tissue. Concentrations in sporulating and in nonsporulating infected tissues were not appreciably different.

Other tree tissues.—Concentrations of N, K, P, and Mg were greater in the branch bark and current-year needles from healthy trees than in older tissues of the same types (Fig. 1). Also, increases in N, K, and P within a tissue age class were correlated with increased sampling height. Magnesium was more concentrated in bottom crown needles than in top crown needles. Sodium levels were similar for all tissues regardless of age or sampling height. In contrast, Ca increased with tissue age and decreased with sampling height.

Needles from diseased trees contained slightly less N and K than needles from healthy trees (Fig. 1), but concentrations were higher in current-year than in older ones.

Generally, the pathogen's presence resulted in lower Ca concentrations (Fig. 1). Moreover, Ca distribution was similar in both healthy and diseased trees; and older tissues contained more than did younger tissues. But, regardless of age, tissues from lower portions of trees had more Ca than did higher portions.

Blister rust stimulated all tissues to accumulate Mg, P, and Na, but Mg and P were highest in young tissues.

DISCUSSION.—All needles from diseased trees had lower N and K concentrations and higher P and Mg levels than needles from noninfected trees. Nitrogen, K, Mg, and P were highest in tissues that supported *C. ribicola* sporulation and lowest in bole bark. Solute levels in yellow margin tissue fell between these extremes. Data reported here on the solute levels in tissues of rust-free western white pines are consistent with those published by other authors working with other members of the genus *Pinus* (14, 21, 22).

Solute accumulations in cankers are similar to the metabolic sinks of diseased annuals (7, 18). Although the specific mechanisms involved have yet to be elucidated, solute concentrations could be associated with metabolism of the host, the pathogen, or both (8, 9, 12, 16).

The results presented suggest that the blister rust fungus regulates the accumulation or loss of certain molecules in specific areas of a canker, and indirectly in the entire tree. The implications of these findings are important in the development of two related areas of research: (i) translocation and accumulation of fungicides in the control of blister rust; and (ii) use of remote sensing in disease incidence survey.

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