A POSSIBLE MECHANISM RELATING INCREASED SOIL TEMPERATURE TO FOREST DECLINE

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Abstract. Nutrient cations are removed from the soil by uptake in biomass, and by leaching as a result of soil acidification. Such acidification results from acid deposition and/or from HNO₃ formed by mineralization and nitrification of humus, when at a rate in excess of the tree's nutritional requirements. This has been found to occur during and following periods of increased temperature and reduced rainfall. The cumulative loss of either Ca²⁺, Mg²⁺ or K⁺ by one or more of these processes, if greater than the amount released from the specific minerals in that soil, leads to nutrient deficiency, fine root mortality, poor growth, and eventually to die-back. Trees growing in soils derived from specific minerals in which there is a strong imbalance in the elements from which the exchangeable nutrients are formed, are vulnerable to nutrient deficiency. This paper discusses the relevance of earlier studies, when considered in relation to more recent findings. In Hawaii there have been frequent periods of increased temperature and drought resulting from the El Niño Southern Oscillation. This fact, when considered in relation to the relatively low K content, and its imbalance with Ca and Mg in the lava and volcanic ash on which the trees have grown, could result in K deficiency in the declining ohia trees. It is possible that the unusual periods of increased temperature and drought which have occurred in certain other localized areas may have led to the decline symptoms recently observed. In view of the threat of global warming, this possibility should be investigated.

1. Early Studies in which Poor Tree Growth and Dieback were Related to Nutrient Deficiency and/or Poor Root Growth

Common factors involved in tree dieback episodes which occurred many years ago, when reconsidered in relation to more recent findings, may have relevance to current dieback episodes of yet undetermined cause, such as that in Hawaii. These episodes occurred during, or immediately following, a period of increased atmospheric temperature, and were characterized by a reduction in fine root biomass, and in above-ground symptoms which were, at that time, or later, associated with K or Mg deficiency. These observations may have relevance to possible future effects of global warming.

Yellow birch, growing in certain areas of Nova Scotia and New Brunswick, showed a decline in growth in the 1930s, with dieback symptoms developing during the 1940's. Hawboldt and Skolko (1947) examined the fine roots of trees, after the trees had been felled and the soil hydraulically removed from the roots of the remaining stumps. They found that about 30% of the fine roots were dead on trees having reduced growth rate but still showing a healthy crown. As fine root mortality increased, dieback symptoms developed and increased. They noted that similar dieback symptoms were subsequently observed in Southern Québec and in Northern New Hampshire and Vermont.

Studies in Nova Scotia eliminated the possibility of damage from insects and fungi as a cause of the dieback (Redmond, 1955). Greenige (1953) carefully classified the dieback condition of 147 yellow birch including those without, and with varying, severity of symptoms. During the growing seasons of 1947–1950 he injected dye into the xylem stream and, after felling the trees, measured the pattern showing the height of its ascent. He then measured the moisture content of outer and inner sapwood at various heights in the trees. In addition, he examined the fine root systems on the stumps after hydraulic removal of the surrounding soil. Greenige also concluded that excessive rootlet mortality in otherwise apparently healthy trees is the initial indication of the diseased condition, and that there was a definite relationship between percentage rootlet mortality and crown injury classes. During the early stages, with the crown showing small curled yellowish leaves, there was still adequate conductance of the sap to the top of the tree. He also found that the moisture content of conducting xylem tissue was still unaffected when twigs, but not branches, had died. However, the moisture content in the xylem of the upper part of the tree was reduced in July and August, when bare branches became apparent, and throughout the growing season at later stages of crown dieback.

It was known that in certain soils poor fine root systems developed in isolated trees following the harvesting of the adjacent trees. Subsequently, crown dieback developed on these trees and this suggested that in such cases increased soil temperature, resulting from increased exposure to sunlight, could be involved in the fine root mortality. During this period there had been decreased precipitation and an increase in temperature of 1°C to 2°C in Nova Scotia, and to test the possibility of such a relationship, Redmond (1955) artificially heated the soil under a healthy yellow birch throughout the growing season. He found that the death of fine roots increased with temperature and that a 2°C increase resulted in the death of 60% of the fine roots, compared with 6% in the control area.

Manion (1981), discussed the decline of ash in New York State, which occurred at about the same time as that of yellow birch, and of maple during the 1950’s and 1960’s. He noted that they all followed the same course as that described for birch. This involves a predisposing increase in temperature leading to fine root degeneration, reduced growth, yellowing and reduced size of foliage, with premature fall, followed by twig and branch dieback. Although no nutritional studies were carried out in connection with early hardwood dieback episodes, the similar development of small chlorotic leaves, and their initial loss from twigs, followed by branch dieback, as described by Greenige (1953) and by Manion (1981) were subsequently observed in the 80’s by Carrier (1986) in Québec, and shown to result from K deficiency by Bernier and Brazeau (1988).

Dieback of conifers was also observed in certain areas. During the 1930’s conifers had been planted on abandoned farmland on a glacial outwash soil in Northern New York State, now referred to as the Pack Forest. During the next decade the young trees showed poor growth, with short and discolored foliage which was prematurely lost. It was found that this resulted from K deficiency. According