The Variability of Snowcover as a Factor in Forest Decline

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The presence of a persistent winter snowcover is characteristic of the Northern Hardwood Forest Region. The absence of snow of sufficient depth to prevent deep soil frost penetration has occurred periodially, usually with marked damage to deciduous tree species. Pomerleau (1944), for example, observed that a forest dieback in the Appalachian Mtns. of southern Quebec had followed the "open" winter of 1932; the dieback and mortality on sugar maple (Acer saccharum Marsh.) occupying wet soils of Beauce County was observed to have persisted for over a decade.

To test his hypothesis that the lack of a normal snowcover had incited dieback, Pomerleau (1989) conducted two experiments in the early 1950's in an attempt to resolve the origin of widespread dieback then prevalent on yellow and white birch (Betula alleghaniensis Britton, B. papyrifera Marsh.) over eastern Canada and the northeastern United States.

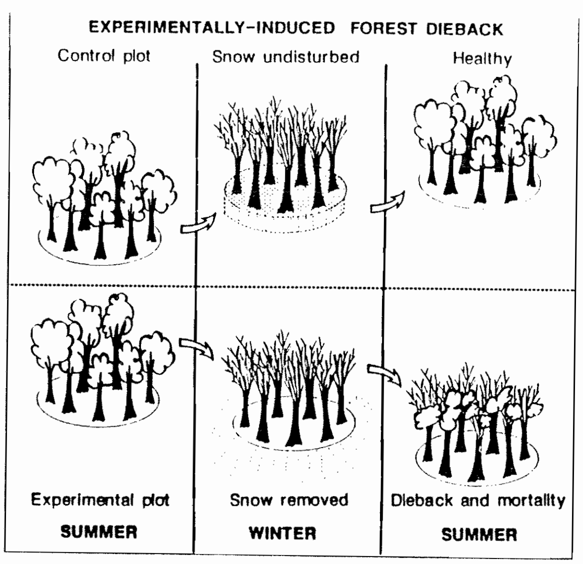

Figure 1. Snow removal experiment conducted in a sugar maple - yellow birch stand from September 1954 through August 1955 at the Duchesnay Experimental Forest 25 km northwest of Quebec City (Pomerleau 1989). Tree condition, air temperature, soil temperature to 130 cm, and soil heaving were measured throughout the treatment period on control and experimental plots, each about 10 meters in diameter.

In the first experiment, crown dieback was experimentally induced in a sugar maple-yellow birch stand simply by removing accumulated snow over the December through March period (Fig. 1). On the treatment plot, there was soil frost penetration to 130 cm (vs. none on the control site), soil ice lense formation, ground heaving (to about 46 cm), and abnormally late soil thaw (last week of June). Observations on tree condition indicated a marked divergence by July or August with normal healthy trees on the control plot in contrast to marked crown dieback, root mortality and full tree death on the treatment plot (Pomerleau 1989).

An historical reconstruction of yearly snowdepth indicated that the long-term relationship with known levels of forest dieback in southern Quebec (Fig. 2) was more complicated than Pomerleau's experiment might suggest. Although 1932 stood out as an open winter, the onset years of major dieback episodes (1925, 1937, 1981) did not. Minor episodes in 1949 and 1954 and the severe dieback of the 1980 decade occurred in years with little snow (<10cm) over 40-60% of the winter period (D, J, F).

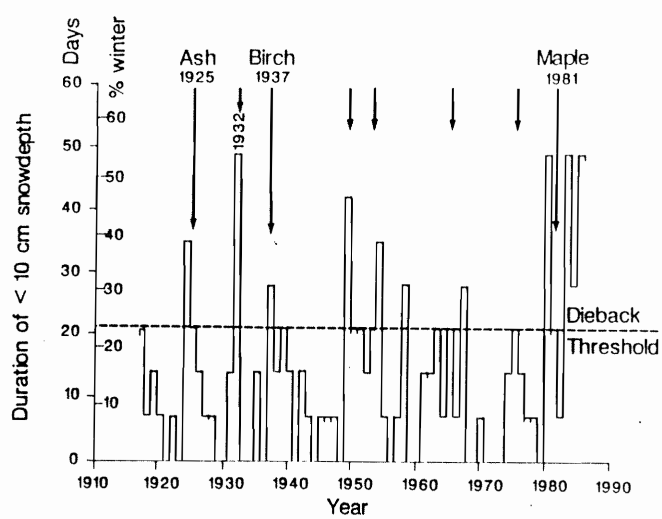

Figure 2. The number of weeks in each year, 1917 to 1985, with less than 10 cm of snow depth in winter (D,J,F) at Lennoxville, Quebec.

In an attempt to refine his initial observations in the field, Pomerleau designed a second experiment, in this case performed with seedlings of yellow birch under controlled laboratory conditions (soils and roots frozen, stem at room temperature). Pomerleau (1989) demonstrated that dieback occurred after 10-20 days probably as a result of acute frost desiccation; after 30 days of soil frost, all seedlings had died (Fig. 3).

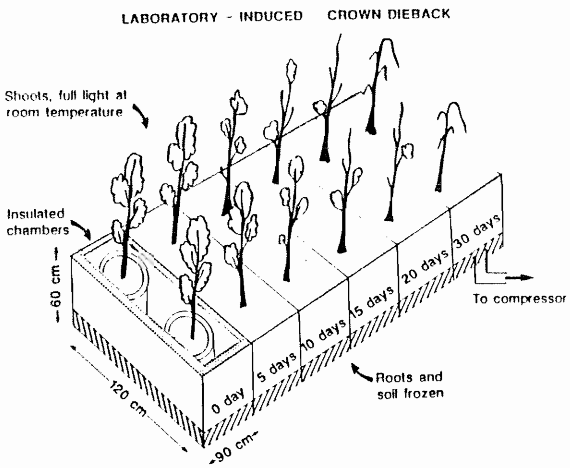

Figure 3. Laboratory acute frost desiccation experiment conducted on six pairs of yellow birch seedlings (Pomerleau 1989). While shoots were maintained at room temperature under fully lighted conditions, soil and roots were maintained below 0°C over periods varying from 0 to 30 days. Increasingly severe dieback and mortality occurred with 10 days or more of soil frost.

Although conducted in the 1950's and never published, Pomerleau's studies remain the key experimental evidence on the role of freezing stresses in causing forest dieback. Using the results of Greenidge (1951) and evidence from modern stress physiology research, Auclair (1989a) recently proposed that forest dieback episodes were the result of sapwood cavitation injury (Tyree and Sperry 1989) induced by winter thaw-freeze events and by the incidence of soil frost in late spring. Two lines of evidence supported this contention. Marked winter thaw characterized the onset of each of the major dieback episodes in Northern Hardwoods known to have occurred this century (Auclair 1989b, 1989c). Second, widespread severe dieback on sugar maple was first evident in Quebec in 1981. An event analysis of the February 1981 thaw indicated that warming was sufficiently prolonged and intense (maximum 17.5°C) to have initiated sapflow and, on some trees, the flush of flower and leaf buds. Rapid freezing events on March 3 and March 14-17 (-23°C minimum) almost certainly resulted in tissue kill and cavitation injury; moreover, in view of the complete meltdown of the snow pack (Fig. 4) in February, deep soil frost penetration was likely. The corresponding surge in streamflow on the Chaudière River in the area of the most intense forest damage provided a useful indicator pattern of winter temperature anomalies; the pattern of abnormally high winter streamflow was also evident in 1925 and 1937 at the onset of dieback on ash (Fraxinus sp.) and birch, respectively (Fig. 5). The real significance of the hydrological peak at the onset of each dieback episode was not only the incidence of thaw but that the subsequent freezing in late winter or early spring occurred at a time when the soil was fully saturated and hence likely to have frozen to great depth.

In conclusion, the primary mechanism of dieback in Northern Hardwoods is pronounced winter thaw-freeze and/or the incidence of deep soil frost in late spring; although these conditions can result in tissue-kill, it is injury in the form of irreversible sapwood cavitation that results in persistent dieback.

References

AUCLAIR, A.N.D., 1989a. Cavitation as a mechanism of dieback in Northern Hardwoods. In Recherche sur le Dépérissement des Érablières, Centre de Recherche Acéricole, Québec, Ministère de l'Agriculture, des Pêcheries et de l'Alimentation, Atelier, February 23-24, 1988, St. Hyacinthe, Quebec. Canada. 5 p.

AUCLAIR, A.N.D., 1989b. Climate theory of forest decline In D.P. Lavender (ed.) Proceedings of the IUFRO Conference on Woody Plant Growth in a Changing Physical and Chemical Environment, July 27-31, 1987, University of British Columbia, Vancouver, British Columbia. Canada. 28 p.

AUCLAIR, A.N.D., 1989c. An historical overview of forest decline in eastern Canada. In Proceedings of the 70th Annual Meeting of the Woodlands Section Canadian Pulp and Paper Association, March 21-22, 1989, Montréal, Québec. Canada. 9 p.

Canada Department of the Environment, 1988. Quebec Historical Streamflow Summary to 1986. Inland Waters Directorate, Water Resources Branch, Water Survey of Canada, DSS Cat. No. EN 36-418/1986-8 Ottawa. Canada.

GREENIDGE, K.N.H., 1951. Dieback: A disease of yellow birch (Betula lutea Michx.) in eastern Canada and the adjacent United States. Ph. D. Thesis. Department of Biology, Harvard University, Boston, Massachussetts. USA. 300 p.

LARCHER, W., and BAUER, H., 1981. Ecological significance of resistance to low temperature. In O.L. Lange, P.S. Nobel, C.B. Osmond and H. Ziegler (eds) Physiological Plant Ecology 1:403-437. Springer Verlag, New York, USA.

POMERLEAU, R., 1944. Observations sur quelques maladies non-parasitaires des arbres dans le Québec. Canadian Journal of Research, (Section C) 22:171-189.

POMERLEAU, R., 1989. Personal Communication In S.L. Walker and A.N.D. Auclair. Forest declines in eastern Canada. Federal LRTAP Liaison Office Report, Atmospheric Environment Service, Canada Department of Environment, Downsview, Ontario. Canada.

TYREE, M.T., and SPERRY J.S., 1989. Vulnerability of xylem to cavitation and embolism. Annual Review of Plant Physiology and Molecular Biology 40:19-38.

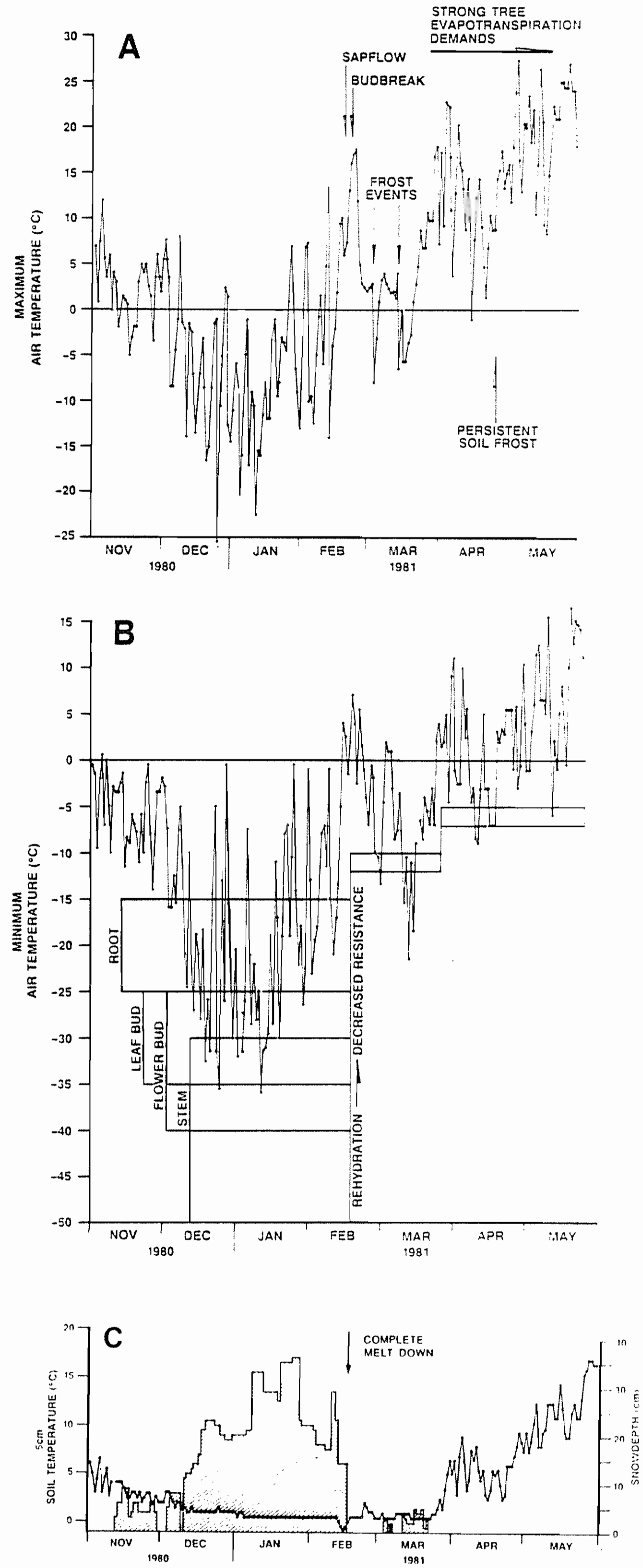

Figure 4. (a) Maximum and (b) minimum daily temperatures November 1, 1980 to May 31, 1981 at Lennoxville, Quebec based on meteorological records (Canadian Climate Centre, AES). Approximate dates of observed sapflow and bud-break are indicated as are representative temperature sensitivity ranges for roots, leaf buds, floral buds, and boles of temperate deciduous trees acclimatized to regions with severe winters (Larcher and Bauer 1981). Timing of frost hardiness decrease following progressive tissue rehydration in mid-February and late March, persistent soil frost and strong evapotranspiration demands on the developing canopy are shown. (c) Snowdepth and soil temperature at 5 cm depth on the Lennoxville meteorological site.

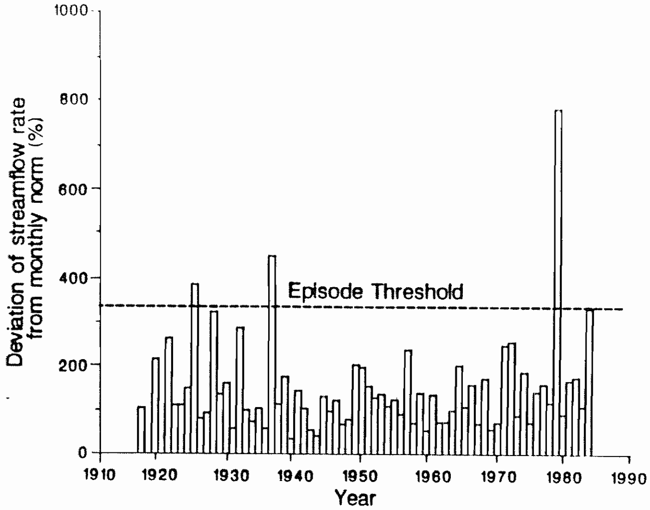

Figure 5. The rate of winter (D,J,F) streamflow on the Chaudière River at St. Lambert de Lévis (1916-26, 1937-86) and at Ste. Marie (1927-1936), Quebec. Values are the percent deviation from the long-term norm of the rate of streamflow of the most aberrant winter month (Canada Department of the Environment 1988).