LETTER

Inconclusive evidence of *Juniperus virginiana* recovery following sulfur pollution reductions

Thomas et al. (1) address a question of great scientific interest: have pollution reductions mandated by the Clean Air Act improved forest health and productivity? Although answers to this question are of great importance, various aspects of this work limit its ability to address this question.

First is the surprising choice of a test species. The bulk of the literature that addresses acid deposition impacts on US trees focuses on two sensitive species: *Picea rubens* and *Acer saccharum*. A plethora of laboratory- and field-based studies using these species have provided a remarkably detailed mechanistic understanding of how pollutant additions of hydrogen ions (H^+) disrupt base cation relations (reducing Ca and increasing Al availability), which then alter tree stress response and carbon relations (e.g., ref. 2). In contrast, we are not aware of any decline in *Juniperus virginiana* associated with acid deposition, and found only one study that assessed its sensitivity to precipitation acidity, which reported no impacts on aboveground or belowground growth (3).

Building on this finding, the mechanisms discussed in Thomas et al. (1) show little connection to accepted understandings of how acid deposition impacts trees. For example, although much incoming acidity historically originated with S pollution, it has been shown that H^+ inputs are the disrupting agent, not S itself (2, 4). Thus, analyses of S in wood rather than the more accepted analyses of Ca and Al seem misplaced. Even the alleged connection between S addition and stomatal function is actually an H^+ and Ca influence (S concentration was equalized between the treatments in ref. 4 cited by ref. 1). The mechanism whereby gaseous sulfur dioxide induces stomatal closure is separate from the influence of acid deposition.

The test location and low sample size used in Thomas et al. (1) are also problematic. The single site evaluated was on a limestone outcrop, a location well buffered against acid deposition-induced soil Ca depletion and Al mobilization. Furthermore, only five trees of greatly varying age were sampled to provide evidence of species recovery, likely contributing to a low expressed population signal for basal area increment: below the 0.85 standard (5).

Finally, there are some inconsistencies in the timeline discussed in Thomas et al. (1). First, it seems odd that the net positive changes in estimated C assimilation and stomatal conductance in the 1930s were attributed to acid deposition when this phenomenon was not reported for the United States until 1972 following long-term monitoring at the Hubbard Brook Experimental Forest in New Hampshire. Second, it is questionable whether the change in $\delta^{13}C$ in 1982 would have occurred when S deposition remained at near record levels (figure 1 in ref. 1). Furthermore, it appears that growth increases began around 1970, before the proposed 1982 turning point in $\delta^{13}C$.

Overall, the timing and context of the Thomas et al. (1) study are important, and some of the methods used are potentially powerful tools for answering questions about the influence of pollution reductions on tree health and productivity. However, various limitations of the current study of *Juniperus virginiana*'s possible recovery from S pollution after the Clean Air Act render it inconclusive.

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