

ACID-BASE STATUS OF UPPER ROOTING ZONE SOIL IN DECLINING AND NON-DECLINING SUGAR MAPLE (*ACER SACCHARUM* MARSH) STANDS IN PENNSYLVANIA

William E. Sharpe and Troy L. Sunderland¹

Abstract: Sugar maple (*Acer saccharum* Marsh) is an important commercial tree species of the central hardwood region which is valued for its wood and maple sugar products. High elevation sugar maple stands in northcentral Pennsylvania have been in serious decline for about the last 15 years with more than 1,200 hectares of maple forest affected. The decline appears to be largely irreversible, leading to the death of the affected trees. Stands at lower slope positions remain generally healthy. The objective of this study was to investigate the role of soil conditions in causing sugar maple decline by studying the acid-base status of soils, plant available soil aluminum and the relative differences in soil Al toxicity to maple seedling roots in declining (47-79 percent mortality) and non-declining (<10% mortality) stands. The acid-base status comparisons for the upper rooting zone (A, B1, B21 horizons) of soils of the sugar maple stands under study are reported here. Five declining and five non-declining stands in close proximity to one another were sampled with soil samples taken from the side walls of hand-excavated shallow soil pits in each stand. The samples were analyzed at the Agricultural Analytical Services Laboratory at The Pennsylvania State University for pH (water paste), and exchangeable Ca, Mg, K and P. Percent base saturation was also calculated. Results indicated that soils from the declining stands had significantly lower exchangeable Ca, Mg and K than the non-declining stands. pH and base saturation were also consistently lower in the declining stands while P was higher. The significance of these differences in acid-base status as a predisposing factor in the observed sugar maple decline requires additional study.

INTRODUCTION

Sugar maple decline is not a new phenomenon. Sugar maple declines have been reported in eastern North America since the early 1950's (Hendershot and Jones 1989). In most cases unusual weather events such as droughts and early frosts or episodes of insect defoliation have been cited as factors contributing to or causing declines (Bauce and Allen 1991, Kolb and McCormick 1993). However, recent severe declines of sugar maple in the Canadian provinces of Ontario and Quebec have prompted investigations into the likelihood that soil acidification and its concomitant suite of potential nutrient deficiencies and imbalances may be a contributing or predisposing factor in sugar maple decline (Kinch 1989, Hendershot and Jones 1989, Bernier and Brazeau 1988a and 1988b). Aluminum is also a potential contributor to these problems through direct toxicity to fine roots (Thornton and others 1986), by interference with nutrient uptake (Thornton and others 1986, Kelly and others 1990), and by causing precipitation of phosphorus to nonavailable forms (Kinch 1989). Liming and fertilization of declining sugar maple stands in Canada with P and K has been shown to improve decline symptoms (Adams and Hutchinson 1992, Hendershot 1991, Kinch 1989, Ouimet and Fortin 1992).

The purpose of this study was to test the hypothesis that the soils of declining ridge-top sugar maple stands were more acidic than those of the non-declining stands and that this condition has resulted in nutrient deficiencies, reduced radial growth and root development. We report here on the acid-base status of the upper rooting zone (A, B1, and B21 horizons) of soils from the ten stands under study.

¹Professor of Forest Hydrology and Graduate Student, respectively, School of Forest Resources and Environmental Resources Research Institute, The Pennsylvania State University, University Park, PA 16802.

METHODS

Study Area

Ten sugar maple stands were chosen for study based on the severity of decline within each stand (Table 1). All of the stands were located within a 10 km² area along Rock Ridge Road in southern Potter County, Pennsylvania (Figure 1). The study area is part of the Susquehannock State Forest. The declining stands are located at elevations around 700 m. The non-declining stands were located at elevations around 560 m. Stands that had been salvage logged were not included in the study. This made selection of declining stands more difficult since extensive salvage logging of declining sugar maple stands has occurred along Rock Ridge Road.

Five stands with presently identifiable mortality of dominant and co-dominant sugar maples ranging from 47 to 79 percent were characterized as declining. Five additional stands with estimated mortality of 0 to 8 percent were characterized as non-declining. Mortality was assessed based on the mean number of dead sugar maples on three 0.1 ha plots within each stand. Any tree with a living branch, no matter how small, was considered living. Any dead standing or down tree with sufficient attached bark to allow for field identification was counted as dead. Mortality was no doubt underestimated particularly in the declining stands because many trees had been lost in years previous to this study that could no longer be identified as sugar maple and thus were not included in the tally. This fact was evident both from the number of stems on the ground and the very poor stocking of stands exhibiting the worst decline.

Trees with greater than 50 percent crown loss were also tallied. If these trees are added to the dead trees in each stand, the declining stands would have 76 to 89 percent of sugar maples in this category and the non-declining stands would have 0 to 11 percent.

Soils

Soils are classified according to the Soil Survey of Potter County (SCS 1953). The non-declining stands based on their plotted locations on the soil survey map are mostly of the Lackawanna Soil Series. These are for the most part channery silt loams. Declining stands are mapped primarily as Leetonia, Wharton, Bath or Nolo Soil Series. These are stony loamy sands and silt loams.

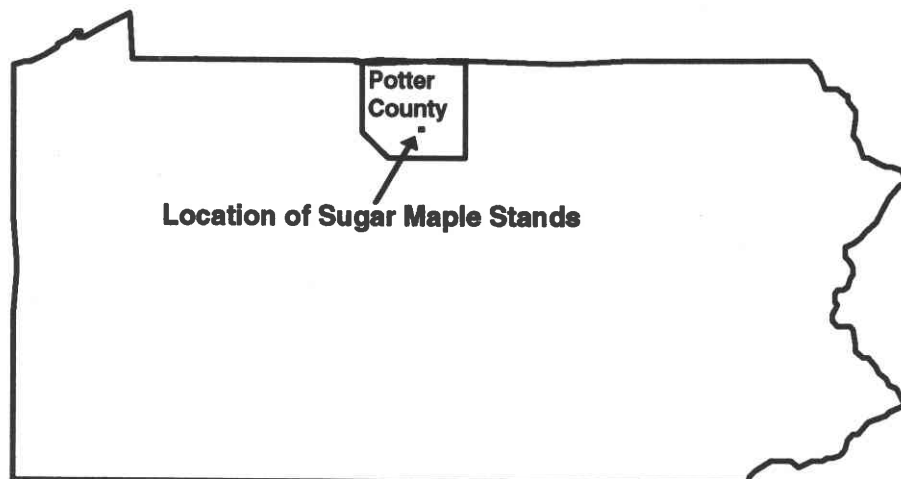


Figure 1. Location of the sugar maple stands within the Susquehannock State Forest in Potter County, Pennsylvania.

Table 1. Sugar maple mortality in the stands under study.

Stand	Mean % dead trees	Mean % dead and >50% crown dead trees
Declining		
D7	78.9 ¹	89.0
D8	74.9	88.6
D4	63.8	85.2
D5	53.1	84.8
D6	47.4	76.2
Non-declining		
ND6	8.3	11.0
ND7	7.0	7.0
ND2	2.2	4.3
ND5	0.0	0.0
ND1	4.5	4.5

¹Mean percentages of all declining vs. non-declining stands in both dead and dead plus >50% crown dead categories were significantly different at $\alpha \leq 0.05$.

Soil samples were obtained from the face of hand-excavated shallow soil pits. Samples were collected by individuals wearing plastic gloves by scraping soil from a clean pit face with a large plastic spoon. Soil descriptions for the soils mapped on each site were used to determine soil profiles in the field. Composite samples were collected from the A, B1, and B21 horizons in each soil pit. A total of 15 samples were collected from each stand. All samples were collected near living sugar maple trees. Samples were placed in plastic bags and transported to the Agricultural Analytical Services Laboratory where they were analyzed for pH, CEC, exchangeable Ca, Mg, K, and P, and acidity by the methods described in NDSU (1988). A percent base saturation was also calculated.

Statistical Analysis

Soil chemistry data were analyzed using the SAS mainframe computer package (SAS 1985). Summary statistics, including means, standard deviations, and standard errors, were calculated for each soil chemical parameter in each forest stand using the MEANS procedure. Significant differences in soil chemistry between declining and non-declining stands were determined using a two-factor nested analysis of variance (PROC NESTED in SAS). Significant differences were determined at $\alpha \leq 0.05$ unless otherwise noted. The Tukey Studentized Range Test was used to test for significant differences in mortality between stands.

RESULTS AND DISCUSSION

The results of the soil chemical analysis are presented in Table 2. The pH of the soils for the declining stands was lower than that of the non-declining stands but the difference was not significant ($P=0.29$). Base saturation was also lower on the declining stands but was also not significant ($P=0.14$). The mean base saturation of the soils in declining stand 5 was 10.2 percent while the mean of the other four declining stands was only 5.25 percent. Without stand 5 the difference in base saturation between declining and non-declining stands was significant. There were very few live trees remaining in stand 5 and most of these were at the edge of the former stand; consequently, it is possible that sampling near these trees in this stand biased the results toward more favorable soil chemistry.

Table 2. Comparisons of mean soil chemistry for declining and non-declining stands.

	Declining	Non-declining	P-value ¹
pH	4.24	4.46	0.29
exch. Ca (meq/100 g)	0.56	1.04	0.03
exch. Mg (meq/100 g)	0.17	0.25	0.05
exch. K (meq/100 g)	0.09	0.14	0.04
exch. P (lbs/acre)	50.6	18.9	0.06
% base sat.	6.36	9.39	0.14

¹Probability that the means are not significantly different.

Base saturation values for forest soils of less than 10 percent are problematic with respect to aluminum availability (Cronan and others 1989). Both the declining and non-declining stands had base saturation values of less than 10 percent although the non-declining mean was 9.39 percent. Our estimates of exchangeable Al (0.01 M SrCl₂ extractable) are not complete as of this writing, but it is expected that they will be high in both declining and non-declining stands.

Estimates of exchangeable Ca, Mg and K indicate significant differences between declining and non-declining stands (Figures 2, 3 and 4). All of these essential nutrients are less available in the declining stands.

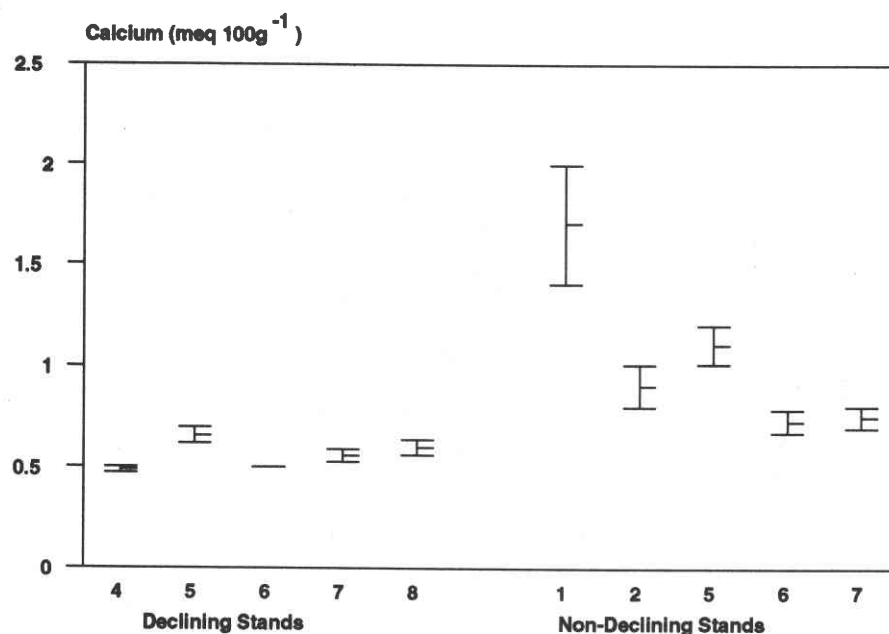


Figure 2. Mean calcium concentrations in soil from each of five declining and five non-declining stands studied. Bars around each mean indicate $\pm$ one standard error.

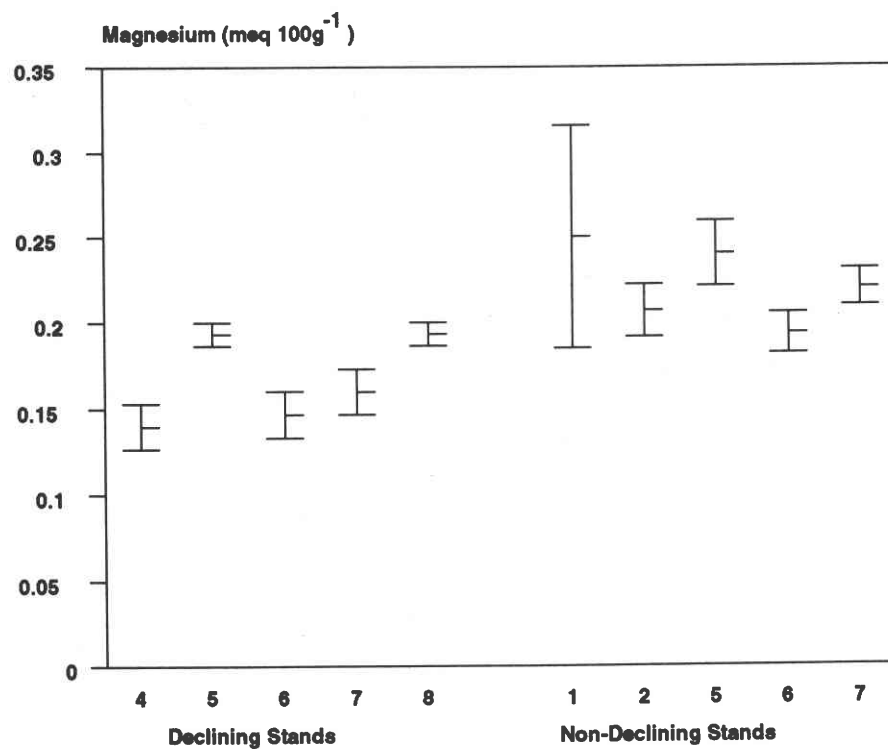


Figure 3. Mean magnesium concentrations in soil from each of the five declining and five non-declining stands studied. Bars around each mean indicate $\pm$ one standard error.

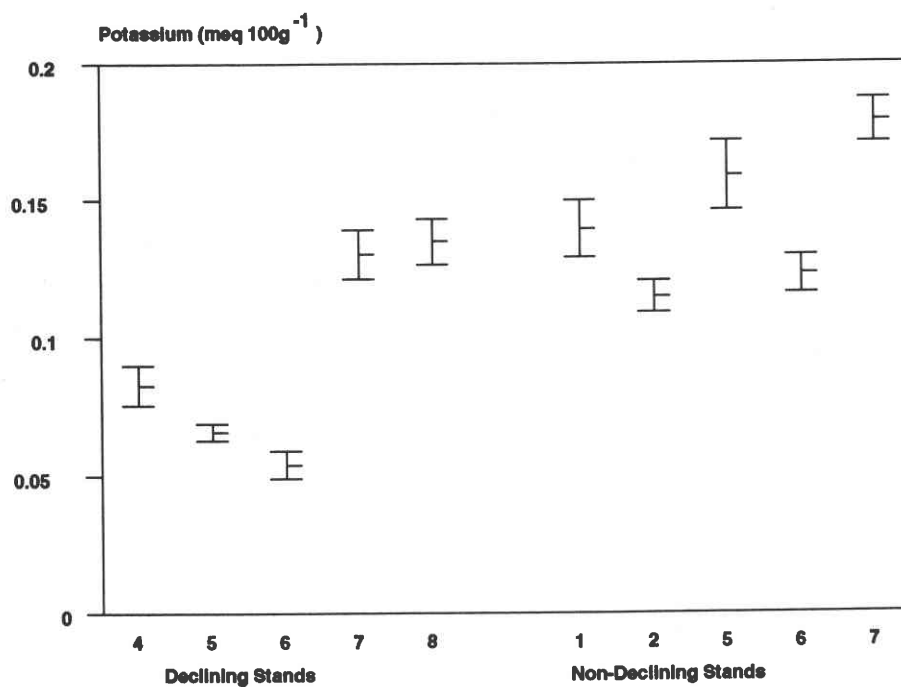


Figure 4. Mean potassium concentrations in soil from each of the five declining and five non-declining stands studied. Bars around each mean indicate $\pm$ one standard error.

This condition alone could be sufficient to explain the difference in decline severity between the stands studied. Kolb and McCormick (1993) reported Mg and possibly Ca deficiencies in the foliage of our declining stand 4 and an additional declining stand on the Susquehannock State Forest. Kinch (1989) reported that Ca, Mg and P were potentially deficient in sugar maples growing in declining stands and that the foliar concentrations of these elements were strongly predicted by soil Al and Ca concentrations and pH. Similarly Roy and others (1985) reported that declining sugar maple stands were often deficient in soil Ca and Mg.

The declining stands had higher exchangeable P than the non-declining stands ($P=0.06$). We tested whether or not this was a consequence of the extraction procedure (Mehlich III) utilized by the Agricultural Analytical Services Laboratory versus a water extraction method suggested by Bingham (1966). Estimated available P was much lower with water extraction. However, declining stands still had higher P although the difference between declining and non-declining stands was not significant. Precipitation of insoluble aluminum phosphate in the presence of high concentrations of available soil Al and low soil pH ($< \text{pH } 6$) has been reported (Cole and Stewart 1982, Cook 1983, Hsu and Bates 1964). If insoluble P were extracted along with available P, as may be the case with the Mehlich III procedure, acidic soils with high P values would have the most fixed, unavailable P; consequently, they could test high for available P but be P limited. Data presented by Kolb and McCormick (1993) did not indicate a P deficiency in our declining stand 4. Foliar analysis currently underway should also indicate whether or not there may be less P available in the declining vs. non-declining sugar maple stands in this study.

SUMMARY AND CONCLUSIONS

The acid-base chemistry of the upper rooting zone soil from five declining and five non-declining sugar maple stands was evaluated. Upper rooting zone soil from the declining stands had lower pH and base saturation, higher exchangeable P and significantly lower exchangeable Ca, Mg and K. This finding is consistent with the results of other studies of soil chemistry in declining sugar maple stands and with the hypothesis that reduced availability of Ca, Mg and K is a potential predisposing factor in the observed decline. Addition of Ca, Mg and K in proper balance should be attempted as a remedy for decline and as a way to encourage sugar maple reproduction in the damaged stands in this area.

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