SIMULATED ACID RAIN EFFECTS ON FINE ROOTS, ECTOMYCORRHIZAE, MICROОРGANISMS, AND INVERTEBRATES IN PINE FORESTS OF THE SOUTHERN UNITED STATES

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ABSTRACT. A 2-yr study evaluated the effects of acid precipitation on the forest floor community. Throughfall was collected at weekly intervals, acidified to pH 4.3 and 3.6, and applied to throughfall excluded 1 m² plots in a stand of loblolly pine (Pinus taeda L.) in south Mississippi, and in a longleaf pine (P. palustris Mill.) plantation in east Texas. Control plots received ambient throughfall which ranged from pH 3.7 to 6.2 in Mississippi and pH 3.8 to 6.7 in Texas. Five plots of each treatment at each location were destructively sampled after 1 yr and the 5 remaining plots were sampled after 2 yr. Chemical analyses were conducted for all collections of throughfall and litter leachate, and for the fermentation layer, rhizosphere, and mineral soil. After 2 yr, comparisons of the pH 3.6 plots with the controls indicated significant decreases in the number, length and biomass of lateral roots, and the percent and number of ectomycorrhizae. Decreases in these root characteristics for plots subjected to applications of throughfall acidified to near-ambient pH 4.3 were also significant or bordered on significance. Numbers of herbivorous mites increased significantly with decreasing pH, but the predaceous mites appeared insensitive. Treated plots had fewer numbers of some groups of the larger invertebrates, especially earthworms, but variation was generally too great to show significance. The acid treatments had little effect on numbers of nematodes, saprophytic fungi or endomycorrhizal fungi.

1. Introduction

Acid deposition has been implicated in the decline of forests throughout the industrialized world (Johnson and McLaughlin, 1986; Klein and Perkins, 1988; Schulze, 1989). Large expanses of forests in Europe as well as the eastern United States show the effects of what is believed to be acid-induced stress. Yet, few studies have demonstrated effects on natural systems at levels approximating ambient. The current study was designed to characterize changes in the abiotic and biotic components of the forest floor associated with increased acid input. Specifically, the effects of increases in acidity of throughfall on leachate and soil chemistry; microbial activity; fine root, lateral root, and ectomycorrhizal development; and invertebrate populations were investigated over a 2 yr period.

2. Methods

2.1. STUDY SITES

Two sites were selected for study: a loblolly pine (Pinus taeda L.) stand located near Bay St. Louis, Mississippi, and a longleaf pine (P. palustris Mill.) plantation near Nacogdoches, Texas. Neither site had been burned for at least 20 yr. The Mississippi site had nearly level, poorly drained, silty to loamy soils of the Atmore and Escambia series (coarse-loamy, siliceous, thermic Plinthic Paleaquults and coarse-loamy, siliceous, thermic Plinthic Paleudults, respectively). These soils were saturated during the wetter months when water would stand at the surface for several days following heavy rains.
Based primarily on the hydric nature of the soil, the site is classified as wetlands (Committee for Wetland Delineation, 1989). The mixed-age loblolly stand was naturally regenerated with a density of 3,660 trees ha\(^{-1}\) and a basal area of 33.5 m\(^2\) ha\(^{-1}\). The sparse understory consisted of a few hardwoods and woody shrubs. The level, well drained soil at the Texas site was a Woden fine sandy-loam (coarse-loamy, siliceous, thermic Typic Paleudalf). This 28-yr-old longleaf pine stand had a density of 1,350 trees ha\(^{-1}\) and a basal area of 36.8 m\(^2\) ha\(^{-1}\). Here, ground vegetation, primarily poison ivy (*Rhus radicans* L.), near some of the plots was treated with a light foliar application of herbicide in June and, again, in July 1987.

2.2. INSTRUMENTATION AND PROCEDURE

A randomized block design with ten replications of each of three treatments (control, pH 4.3, and pH 3.6) provided thirty 1 m\(^2\) plots at each site. In Mississippi, forest floor microrelief was sufficient to permit the placement of plots in areas that were not covered with water during most rainfall events. At both locations, plots were placed at least 3 m apart to insure isolation. Modified tensionless lysimeters (Jordon, 1968) were installed at ground level just below the fermentation (Ao) layer to collect litter leachate from plots of each treatment at three randomly selected blocks at each site.

The forest floor terminology used in this study is defined as follows: Litter layer - the top layer of the forest floor, composed of recognizable needles and other matter of organic nature; Fermentation layer - the thin layer, composed of obviously decomposed organic matter, below the litter layer and immediately above the feeder root zone; Rhizosphere - the zone of soil that is totally permeated by fine roots and visible mycelium mostly emanating from ectomycorrhizae; Mineral soil - the zone below the rhizosphere. The rhizosphere averaged 1.7 and 4.5 cm thick in Mississippi and Texas, respectively. Over 85 percent of the fine root biomass was found within this zone at both sites.

Throughfall was collected on elevated 2 m\(^2\) corrugated fiberglass sheets located adjacent to each study block and held in plastic containers. The maximum volume that could be stored per container was 120 L or the equivalent of 6 cm of throughfall. Three collectors identical to the throughfall collectors were placed in open areas and provided samples for measurement of ambient rainfall at each site. Polyethylene stemflow collectors (Likens and Eaton, 1970) attached to trees in Mississippi (3) and Texas (2) were used to further characterize the sites.

A portable pH meter with automatic temperature compensation was used in the field to measure the H\(^+\) activity of rainfall, throughfall, and stemflow samples. Water samples for chemical analyses were collected in acid-washed, 125 mL polyethylene bottles and refrigerated (5\(^\circ\)C).

The acidity of collected throughfall was adjusted to pH 4.3 or 3.6 with a mixture of H\(_2\)SO\(_4\) and HNO\(_3\) (National Bureau of Standards, 1984; Irving, 1985) and sprinkled on the plots within 7 d of each event. Stock solutions of HNO\(_3\) and H\(_2\)SO\(_4\) were made by adding 90 ml of 70 % HNO\(_3\) or 240 ml of 96.5 % H\(_2\)SO\(_4\) to 1 L of distilled water. One mL of each of these acid solutions was added to 1 L of distilled water to yield a solution of approximately pH 2.0. This solution was then used in the field to adjust the throughfall pH. In Mississippi, treatment was postponed when standing water was present in the study area.

Between applications, plots treated with acid solutions were covered with corrugated fiberglass sheets raised 20 cm above the forest floor to allow for air circulation. Plastic gutters (2.4 m) channeled the throughfall running off the plot covers away from the plots. The control plots received uncollected ambient throughfall during the first yr; during the second yr all plots were covered and additional ambient throughfall was collected for application to the control plots.

One yr after treatment began, one-half (5) of the 1 m\(^2\) plots of each treatment at each site were destructively sampled. A 0.09 m\(^2\) area at the center of each plot was removed in layers (fermentation, rhizosphere, and mineral soil) to a depth of 15 cm, placed in plastic bags and transported to the laboratory for chemical and biotic analyses. Litter and fermentation layers from an additional 0.09 m\(^2\) area were removed for dry-weight determinations. The remaining litter from each plot was placed on a