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Acid Rain: A Problem on Agronomic Crops and Soils in Kentucky??

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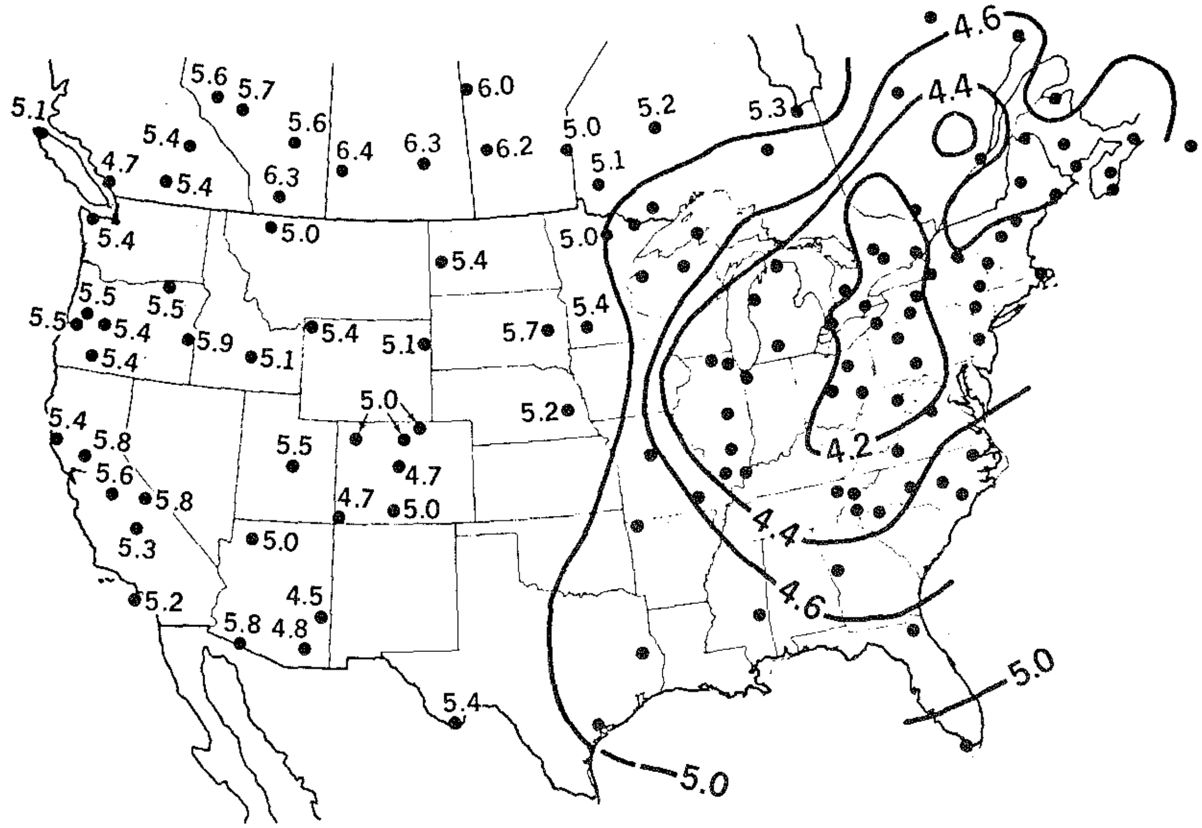
Introduction

Although the general issue of atmospheric pollution is complex, the image of beautiful lakes without aquatic life has focussed public attention on the acidity, or pH, of rainfall. Kentucky does receive acid rain (see map). This discussion will seek to define atmospheric acidity and its deposition and describe reported effects on agronomic crops and soils.

Acid Deposition: Definitions and Sources

Atmospheric acidity results from the reactions of sulfur dioxide (SO_2) and the oxides of nitrogen (NO_x) with other chemicals in the atmosphere or with chemicals present in plant tissues, soil minerals and dust following absorption of SO_2 and NO_x. This latter process is termed "dry deposition" since rainfall is not present. Dry deposition can be very important, accounting for up to 90% of the acid deposited in some areas. SO_2 and NO_x result from the burning of fossil fuels and wood in automobiles, homes, and power plants. Ammonia (NH_3) and the ammonium (NH_4^+) ion are also related to atmospheric acidity. Ammonia can be volatilized from several sources, including soils, leaf canopy surfaces, and animal feedlots. The acidification results when ammoniacal N is deposited on the soil surface and converted to nitrate (NO_3^-), a common source of soil acidification in agricultural soils receiving N fertilizer as well.

Acid rain results when water droplets absorb SO_2 and NO_x gases, which then form sulfuric and nitric acid (H_2SO_4, HNO_3). This causes rainfall pH to fall below that of "natural" rain, which would be about pH 5.6 in the eastern U.S. Unpolluted rain water is not "neutral," pH 7, because of the reaction of water with atmospheric carbon dioxide (CO_2) to form carbonic acid (H_2CO_3).



pH of precipitation in 1981 based on data from approximately 100 National Atmospheric Data Program sites in the United States and additional sites in southern Canada. The respective volumes and pH values of precipitation from the precipitation events at individual sites have been combined in such a way as to estimate for each site the pH value the precipitation would have had if it all had been received at one time. The locations of the NADP stations are indicated by dots. No lines have been drawn in the western part of the country, and the average pH value is given at each location because there are too few stations to define pH regions adequately.

(CAST, Spec. Pub. #14, 1985)

Impact on Plants

Rainfall acidity is not uniform, varying both within a single event and between events. Information on both yearly averages and individual episodes is important to the understanding of effects on plants. Field crop research using sulfuric acid (H_2SO_4) at concentrations commonly measured in acid rain has not reduced plant growth. However, direct plant absorption of SO_2 (sometimes termed SO_2 fumigation) has caused injury and yield loss. This exposure decreases and is less injurious as the distance from the emission source increases. Plant SO_2 exposure near large point sources is strongly related to wind direction and velocity, the presence or absence of inversions, and may last for only a few hours. Monitoring data typically indicate that an hourly SO_2 concentration 10 times greater than the average yearly value occurs in about 5 out of every 200 hours (2.5% frequency).

Other factors influence the degree of leaf injury (death of tissue) and economic yield loss to SO_2 exposure. Plant species vary in their resistance (corn is more resistant to SO_2 fumigation than most legumes). The presence of other air pollutants (NO_x, ozone) may modify the SO_2 dose-plant response relationship. Exposures to SO_2 that do not result in leaf injury may be high enough to result in lower rates of photosynthesis for some length of time, depending on crop species, SO_2 concentration during exposure, exposure duration and the number of previous exposures. In research on soybeans with multiple SO_2 exposures at concentrations below those associated with leaf injury, workers in Wisconsin reported an acceleration of chlorosis (yellowing) during senescence and a 10% yield reduction. They also reported a 35% loss in grain yield from repeated SO_2 exposures at concentrations sufficient to result in leaf bronzing. Research conducted on cotton indicates that the fraction of leaf area lost due to a single SO_2 fumigation was somewhat independent of plant growth stage, while the yield loss due to leaf injury was dependent on growth stage. Similar observations would be expected on other annual crops where only reproductive tissues are harvested.

The N and S deposited from the atmosphere are plant nutrients. The amount of N received in this way is relatively unimportant, but the 10-15 lb S/acre received annually across most of Kentucky may account for the lack of response to S fertilizer applications in field research trials.

Impact on Soils

Soil is the end result of several soil forming processes, one of which is soil acidification. Acid deposition, both wet and dry, is only one factor among many in soil acidification. Soil microbes and plant roots contribute to acidity with their growth activity and through decomposition of their residues by other organisms. Basic cations (K, Ca, Mg) are removed from agricultural soils by crop plants and these are replaced by cations newly released from soil minerals, fertilizers, and lime or by acid cations (Al, H, Mn) if other sources are insufficient. The quantity of pure calcium carbonate required to neutralize the acid deposited in annual rainfall (both H^+ and NH_4^+) in Kentucky would be 30-50 pounds per acre, based on National Atmospheric Deposition Program estimates for 1980 and 1981. This amount is small compared to the estimated 350 pounds of calcium carbonate required to neutralize the acidity resulting from a single 100 pound N application for corn.

The soil's ability to resist pH change, termed soil buffer capacity, is related to properties like cation exchange capacity (CEC), clay and organic matter content. Kentucky soils are generally well buffered against pH change unless large amounts of acid forming materials are reacting with a small soil volume, such as occurs at the surface of continuous no-till corn soils.

Summary

There is little evidence that wet deposition of acid (acid rain) is harmful to agronomic crops in Kentucky. In fact, the lack of response to fertilizer S in the state suggests that S deposition may be helping to meet plant S requirements. However, dry deposition of SO_2 may occasionally result in localized crop injury.

Kentucky's agricultural soils are generally well buffered against adverse effects due to acid deposition. Significant increases in soil acidity are due more to naturally occurring acidification processes and the use of fertilizer N than from acid rain in Kentucky.

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