Reclamation and regeneration of boron in high-boron soils

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Although boron is an essential plant nutrient, it becomes toxic to growing plants if excessive levels are present in the root zone. Soils containing high native concentrations of boron occur primarily in arid and semiarid environments where drainage or leaching, or both, are restricted. Soils periodically exposed to water containing appreciable amounts of boron, including groundwater and irrigation water, may also develop elevated levels of the element.

Both classes of soils exist throughout California. The Central Valley has extensive areas of boron-affected soils, especially in the Westside and Valley trough. High-boron soils occur sporadically in other parts of the state where unique natural conditions or human activities enhance boron accumulation.

Before a high-boron soil can be used successfully for farming, its soluble boron content must be reduced to nontoxic levels. The usual procedure is to leach the soil with low-boron water sprinkled or ponded on the surface. Soil boron dissolves in the percolating solution and moves out of the root zone in the drainage water. When the boron concentration in the soil solution is sufficiently low for crop production, water additions to the soil are stopped and drainage is allowed. The soil is considered to be reclaimed.

This state of reclamation, however, is not static. Soluble boron appears to increase after the soil has been reclaimed, and phytotoxic conditions may recur. This phenomenon has been termed "boron regeneration."

Leaching studies

Our research at the University of California, Riverside, funded in part by the Kearney Foundation of Soil Science, has focused on the processes that cause boron to regenerate after reclamation. We have also evaluated some management techniques that may minimize the potentially harmful effects. We examined soils high in native boron as well as those artificially boronated by adding boric acid. A number of reclamation strategies were used to reclaim the soils in the laboratory. The reclaimed soils were equilibrated for 30 days under varying conditions and releached. We evaluated the status of each soil by monitoring boron in the drainage water.

Regeneration occurred in all soils regardless of the boron source or reclamation treatment, suggesting that the causal mechanism is not unique to soils high in native boron. Boron concentrations of 4 ppm or higher in the saturation extract are considered potentially injurious to the cotton and sorghum crops commonly grown on these soils. This threshold was approached or exceeded in several of the soils after regeneration had been allowed.

The experiments indicated that boron recently added to soil was more efficiently leached than was native boron. Boron regeneration occurred even if the soils were allowed to air-dry after reclamation; the amount of regeneration increased with soil moisture content. These results indicate that a fallowed soil will regenerate boron, but the amount will be low. A team of UC researchers led by F. T. Bingham demonstrated this effect in a 1972 field study. Increasing the amount of water used to reclaim the soil reduced the concentration of boron that regenerated. Fast water flow velocities during reclamation decreased the efficiency of boron removal and enhanced boron regeneration. Boron regeneration lessened after each leaching water application in soils reclaimed by intermittent ponding.

These results suggest that a finite quantity of leachable boron exists in an unreclaimed high-boron soil. As this source is progressively depleted by leaching, the ability of the soil to regenerate soil solution boron is diminished. Reclamation procedures that inhibit the degree of interaction between leaching solution and soil will promote boron regeneration.

Causal mechanisms

Boron regeneration can be attributed to two types of processes: dissolution of sparingly soluble sources that are resistant to leaching, and diffusion from portions of the soil bypassed by leaching water.

Boron in soils occurs as a component in and adsorbed on surfaces of minerals and organic matter. During reclamation, the element is rapidly removed from some of these sources and more slowly from others. If leaching is stopped before the sparingly soluble sources of boron are eliminated, the element will continue to come into solution at a low rate. Soil solution boron will therefore regenerate.

Leaching water may bypass portions of the soil during reclamation, primarily when water flow is channeled through large and continuous pores. Native soil boron will be preferentially leached from the soil volume that is accessible to the leaching solution. Using some arbitrary low concentration of boron in the drainage water to signal the achievement of reclamation will result in a soil that is only "apparently" reclaimed. Considerable amounts of solid and dissolved boron may reside in the bypassed soil volume. Soluble boron concentrations in the leachable pores will increase as boron diffuses from the bypassed regions.

We found both mechanisms to operate simultaneously in column systems. The relative importance of each in the field depends on the actual conditions of reclamation.

Soil and water management

Boron regeneration is of agronomic concern only if it causes crop injury. Our research suggests that regeneration of phytotoxic boron concentrations can be prevented by proper soil and water management. The amount of leachable boron remaining in a reclaimed soil determines the rate and final concentration of regenerated boron. Long-term continuous ponding will effectively eliminate sources of regenerable boron; however, this procedure requires large volumes of water, which create cost, drainage, and disposal problems. Intermittent ponding, coupled with extended regeneration periods between water applications, required some 60 percent less water to remove the same amount of boron as continuous ponding. The substitution of regeneration ability for leaching water requires further study. Reclamation by sprinkling may also enhance efficiency of boron removal.

Irrigations that produce drainage will prevent regeneration of phytotoxic boron concentrations after crop planting. High-boron soils can be effectively reclaimed of regenerable borons. The final boron status of such soils will be determined by irrigation water quality and management practices.

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