Fertilizing by ion exchange promising

Anaheim

Scientists at the U.S. Geological Survey Center in Denver have been using ion-exchange techniques to apply phosphorus fertilizers to crops. The approach could prove particularly useful in tropical soils that rapidly fix conventionally solubilized phosphates. A potential side benefit is the control of nitrogen runoff pollution from cattle feedlots. Greenhouse tests have been promising, but the idea hasn't yet been tested in field trials.

USGS geologist Dennis D. Eberl described the work in a presentation to members of the Division of Fertilizer & Soil Chemistry. "Rather than treat the soil with soluble fertilizer, we add plant nutrients to soil in the form of sparingly soluble natural minerals that are rendered more soluble by also adding an ion exchanger," Eberl explains. He adds that the method is based on the assumption that plants don't necessarily need a large amount of soluble nutrients at one time, but rather a continuous supply of nutrients at lower concentrations.

The basic idea of making soluble phosphorus fertilizers by treating phosphate rock with acid hasn't changed much since the development of superphosphate fertilizers in the early 19th century, Eberl notes. Processes have been refined since those days, he admits, but "We feel that soluble fertilizer isn't the elegant solution to the problem."

For example, Eberl notes, the acidulation process produces huge amounts of waste gypsum and clay that present difficult disposal and land reclamation problems. And the processing plants cost hundreds of millions of dollars. Furthermore, when the solubilized phosphate fertilizer is put into the soil, some or most of the phosphorus reacts with soil constituents and once again becomes insoluble. Fixation of soluble phosphorus is especially a problem in some tropical soils.

Phosphate rock can be applied directly to soil. But apatite, its main phosphate component, is only sparingly soluble in water. That limits its usefulness as a fertilizer. What Eberl and principal coworker Tung-Ming Lai have done is to mix the phosphate rock with an ion exchanger, such as an ammonium zeolite. Rather than "push" the phosphate in the direction of solubility, as acidulation does, the ion exchanger "pulls" it in that direction by acting as a sink for the calcium ions that are released into solution as the apatite dissolves. Then, with lower Ca^{2+} activity, more apatite can dissolve—until it's all dissolved, provided there's enough ion exchanger in the system.

Meanwhile, of course, NH_4^+ ions are being released from the zeolite into solution, so that nitrogen as well as phosphorus is made available. Eberl says there are at least two ways to saturate the ion exchanger with ammonium ions: by using the exchanger to remove ammonia from industrial or sewage effluents (a process already in use, he notes), or by exposing hydrogen-saturated exchanger to ammonia gas.

One could use natural potassium or sodium zeolites instead of ammonium-saturated zeolites, Eberl says. However, they wouldn't supply nitrogen to the crop. And the sodium could be toxic to plants.

A group at the University of Guelph, in Ontario, headed by Ward Chesworth and Peter van Straaten, is saturating the zeolite with ammonium ions by reacting it with manure and cow urine. "This process offers the possibility of using zeolite to reduce pollution and to trap nitrogen in animal feedlots," Eberl says. "When the zeolite starts to smell, it's ready to be mixed with phosphate rock."

The ingredients needed to make ion-exchange fertilizers—phosphate rock and an exchanger, such as zeolite, peat, or smectite—are widely available in near-surface deposits, Eberl says. Indeed, the Guelph team is experimenting with the method because they're trying to develop low-cost, locally available fertilizers for Tanzania.

Plants treated with ion-exchange fertilizer show that it works

"Our chemical data suggest that ion-exchange fertilizers may be particularly effective in high P-fixation tropical soils," Eberl comments. In contrast to soluble phosphates, he explains, the ion-exchange-solubilized phosphate is released slowly, and therefore isn't completely fixed early in the growing season.

The ion-exchange fertilizers have some shortcomings. For example, they tend to be heavy and bulky, so local manufacture would be desirable. They won't work well in soils that contain such calcium minerals as calcite and gypsum. And possible toxic effects from the fluorine, rare earths, and uranium that are associated with some phosphate ores would have to be dealt with.

Despite those concerns, greenhouse experiments, carried out by agronomist Kenneth A. Barbarick at Colorado State University, have been highly encouraging, Eberl says. Yields of crops fertilized with the ion exchange products were two or three times as high as those of crops fertilized with conventional solubilized phosphates. Even if large-scale field tests show that ion-exchange fertilizer is too costly for general use, it may still find special uses in greenhouses, in home gardens, and for specialty crops, Eberl says.

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