How much nitrogen does corn get from fertilizer? Less than farmers think

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Corn growers seeking to increase the amount of nitrogen taken up by their crop can adjust many aspects of fertilizer application, but recent studies from the University of Illinois Urbana-Champaign show those

tweaks don't do much to improve uptake efficiency from fertilizer. That's because, the studies show, corn takes up the majority of its nitrogen—about 67% on average—from sources occurring naturally in soil, not from fertilizer.

The evidence for soil as corn's major nitrogen source came repeatedly over the course of four studies, the first published in 2019 and the rest more recently.

In all four studies, researchers in the Department of Natural Resources and Environmental Sciences (NRES) in the College of Agricultural, Consumer and Environmental Sciences (ACES) at U. of I. labeled fertilizers with a naturally occurring isotope of nitrogen, known as 15N, and applied it in the field at different rates, forms, placements, and timings.

After each harvest, the researchers analyzed corn biomass and grain for its nitrogen content, attributing labeled 15N to fertilizer and unlabeled nitrogen to soil sources. In all four studies, which included both poor and fertile soils in Central Illinois, most of the nitrogen in corn at harvest was unlabeled.

"My hope would be that producers would just realize the magnitude of these numbers. They're purchasing this nitrogen and it's not all getting into the crop," said Kelsey Griesheim, who completed the studies as an NRES graduate student and is now an assistant professor at North Dakota State University. "It's important to make them aware of it, so that when they're looking at their bottom line and how much they're spending on nitrogen, they realize the situation."

Griesheim's 2019 study found only 21% of fertilizer nitrogen made it into the grain when applied in the fall as anhydrous ammonia. The result made some sense, as fall-applied fertilizer lingers in the soil for months

before corn is planted, and then has to last throughout the season to nourish the growing crop.

Incidentally, the study also found nitrification inhibitors, often applied with anhydrous to slow transformation from ammonia to more-leachable nitrate, didn't help to enhance nitrogen uptake from fertilizers.

Assuming pre-season and in-season application would achieve greater uptake than fall-applied nitrogen, Griesheim tried those tactics in her three more recent studies.

Jumping forward to planting season, Griesheim applied 15N-labeled urea-ammonium-nitrate (UAN) at planting in subsurface bands using 2 x 3 placement, surface dribble, and drag-chain applications at 80 pounds per acre. Reaching up to 46% 15N content in corn biomass, banded placement was more efficient than broadcast fertilization, which only reached 34% in the most optimal sites.

"No question, banding is more efficient than broadcasting nitrogen. That was very clear from the data," Griesheim said. "However, whether we applied one band or two bands, or whether we used the 2 x 3 placement or a drag chain, there weren't a lot of differences in efficiency."

Griesheim also tested fertilizer placement during in-season growth, or sidedressing, applying 200 pounds per acre of 15N-labeled UAN with a Y-drop attachment that delivers liquid fertilizer at the base of a growing corn stalk. In this case, Griesheim split the application between planting and the V9 growth stage. She compared the Y-drop application against subsurface placement at both growth stages.

"When split between two application times, 15N uptake was higher at sidedressing than at planting, but even when applying in-season, more nitrogen was derived from soil than fertilizer (averaging 26% in grain

and 31% in biomass from fertilizer)," Griesheim said. "We didn't see a difference between the Y-drop and subsurface applications for five of the six study years, but under conditions conducive to volatilization, uptake was greater with subsurface applications."

Finally, Griesheim labeled multiple fertilizer forms—UAN, potassium nitrate, and liquid urea—with 15N and applied them as surface sidedress applications with a Y-drop applicator. Surprisingly, uptake was greatest when fertilizer was applied as potassium nitrate, followed by UAN, then urea.

"It was interesting that nitrate emerged as the most efficient of the three sources, despite weather conditions that were fairly conducive to nitrogen loss by leaching or denitrification," said Richard Mulvaney, professor in NRES and co-author on all four papers. "Laboratory incubation experiments that were part of the same study showed this was due to ammonia volatilization and immobilization by soil microbes."

The full body of work suggests there are things farmers can do to increase nitrogen uptake from fertilizers: namely, apply nitrate-based sources in-season while the crop is actively growing. But the recurring lesson that soil supplies the greatest amount of nitrogen to corn is an important one that should lead to changes in nitrogen management, the researchers say.

"If the soil is the main source of nitrogen for crop uptake, which it almost always will be, we need to take the soil into account. It's just that simple. Otherwise, with factors like timing, rate, placement, and form, we're tweaking, but probably won't find a miraculous increase in efficiency using those approaches," Mulvaney said. "We really should go toward adjusting rate according to the soil and the soil-supplying power, going towards variable-rate nitrogen."

Overapplying nitrogen that doesn't make it into the crop not only affects farmers' bottom lines, the excess can leach into waterways or transform into greenhouse gases, adding to agriculture's environmental footprint.

"Using fertilizer nitrogen uptake efficiency as a means of ranking fertilizer practices makes a lot of sense," Griesheim said. "More fertilizer in the crop is good for the farmer, but it also means less fertilizer left in the soil which is good for taxpayers and surrounding ecosystems. It's a win-win."

More information: Kelsey L. Griesheim et al, Isotopic comparison of ammonium and nitrate sources applied in-season to corn, *Soil Science Society of America Journal* (2023). DOI: 10.1002/saj2.20531

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