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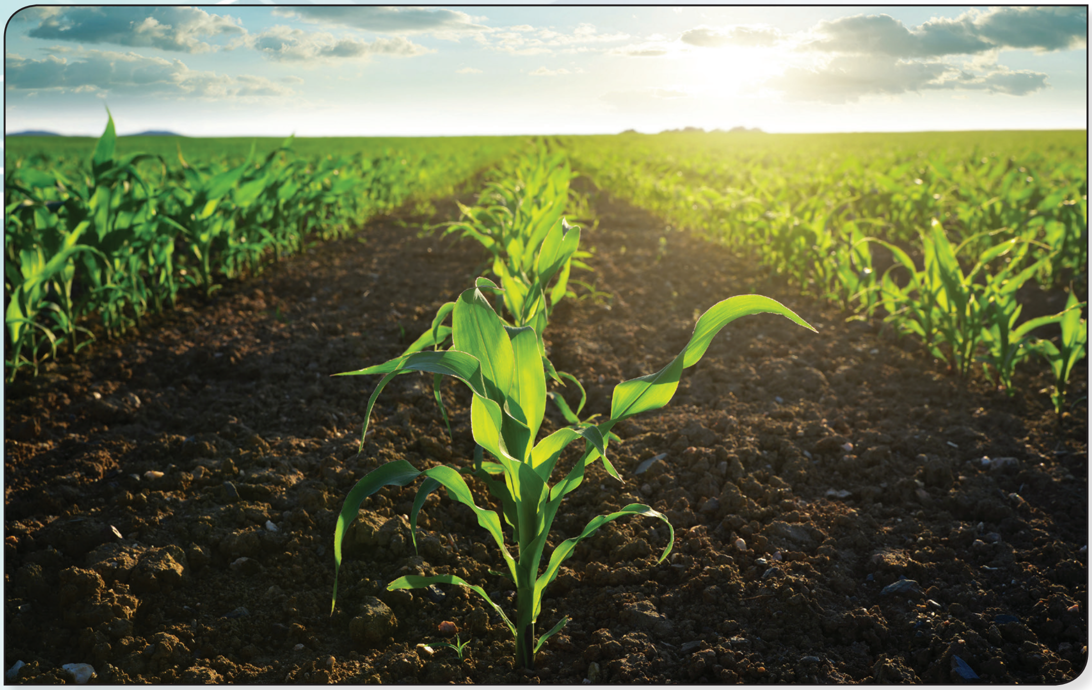
WHAT WE SHOULD BE SAYING WHEN WE TALK ABOUT NITROUS OXIDE EMISSIONS



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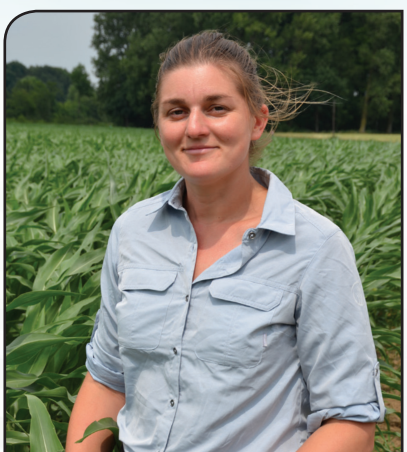

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I was speaking to an agronomist at a meeting recently, and he brought up a good point. When agricultural researchers discuss gaseous losses, we tend to focus on ammonia volatilization or nitrous oxide (N_2O) emissions. However, when it comes to N_2O emissions, losses are generally small—often less than 3% of fertilizer inputs.

Why does agronomic research focus on N_2O emissions so much if N_2O losses are such a small fraction of fertilizer inputs?

Researchers care about N_2O losses because it is a potent greenhouse gas, and agriculture is a major contributor. Aside from the public policy implications, such small losses may not be a high priority for growers. However, this particular agronomist keenly pointed out that N_2O emissions do not occur independently of other losses. And so, when we talk about N_2O losses, we are really talking about much more.

What other losses of nitrogen coincide with N_2O?

Nitrous oxide can be emitted during nitrification, a process carried out by nitrifying bacteria and archaea in two main steps:

NO
↑

Step 1: $2NH_4^+ + 3O_2 \rightarrow 2NO_2^- + 4H^+ + 2\,H_2O$

NO N_2O
↑

Step 2: $2NO_2^- + O_2 \rightarrow 2NO_3^-$

As demonstrated in this reaction, two other forms of nitrogen (besides N_2O) are at risk of being lost. The first is nitric oxide (NO). Nitric oxide may not be a major air quality concern in rural areas; but in urban areas, NO gas can react with hydrocarbons, oxygen, and sunlight to form smog near our land's surface. Secondly, nitrate is the final product of

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nitrification. While nitrate is a good source of nitrogen for crops, this molecule is mobile in most agricultural soils and can be readily leached to groundwater if not captured by plant roots.

Nitrate can also be reduced to gaseous forms of nitrogen during denitrification. This transformational process has four steps carried by microbes capable of respiring nitrate in the absence of oxygen:

Step 1: $2NO_3^- + 4H^+ \rightarrow 2NO_2^- + 2H_2O$

Step 2: $2NO_2^- + 4H^+ \rightarrow 2NO + 2H_2O$

Step 3: $2NO + 2H^+ \rightarrow N_2O + H_2O$

Step 4: $N_2O + 2H^+ \rightarrow N_2 + H_2O$

During denitrification, three forms of nitrogen gas are formed incrementally: NO, N_2O, and dinitrogen (N_2). Dinitrogen is considered inert, or unreactive, in the atmosphere, and is the final end product once all steps of reaction are completed. Dinitrogen is considered benign from an environmental perspective. However, a significant amount of nitrogen can be lost as N_2—harming the grower's fertilizer use efficiency. Dinitrogen often exceeds N_2O losses, potentially being more than three times greater[1]. The relative proportions of N_2 and N_2O vary, and relatively less N_2O and more N_2 is emitted under neutral to alkaline pH[2], high soil moisture[3], and lower nitrate concentrations[4]. In comparison, losses of NO gas can be similar in magnitude to N_2O, but NO is favored under drier conditions[5].

The combined losses of N_2, N_2O, and NO can add up and hurt the grower's bottom line. Therefore, considering nitrogen fertilizer decisions that reduce N_2O emissions may not seem like a high priority, but a reduction in N_2O may also coincide with reductions in nitrate leaching, NO, and N_2 losses. For example, the use of nitrification inhibitors may reduce both N_2O emissions *and* nitrate leaching since both are the products/substrates of nitrification and denitrification. While N_2O may not seem like important, it may tell us more than we think.

References

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