PLANT NUTRIENTS

# AdvanSix Sulf-N® Ammonium Sulfate

## New Acidification Values Change Profile of Ammonium Sulfate

*By M. M. Gearhart and D. J. Collamer*
*Certified Crop Advisers*

Liming is a routine crop management practice on many agricultural soils and is a consequence of soil acidification by nitrification of nitrogen fertilizer. Soil acidification values adopted by the Association of Official Analytical Chemists (AOAC) in 1934 suggest that ammonium sulfate (21-0-0-24S) requires three times more lime to neutralize soil acidity compared to ammonium nitrate or urea. As reported in *Soil Science*, August 2008, a critical examination of these values by Chien et al. demonstrates that soil acidification from ammonium sulfate is approximately 25-50 percent less than previously reported, giving ammonium sulfate a more cost-efficient agronomic profile. A growing emphasis on fertilizer efficiency and rising awareness of fertilizer nitrogen effect on greenhouse gas (GHG) emissions are increasing interest in ammonium sulfate, a nitrogen source that resists nitrogen loss from leaching, volatilization and denitrification.

### Introduction

Pierre (1928) predicted that the acidity developed from one mole of nitrogen compound as ammonium sulfate (AS) would be *three times* more than the predicted acidity developed from one mole of nitrogen compound as ammonium nitrate (AN) or urea. In 1934, the Association of Official Analytical Chemists (AOAC) adopted Pierre's prediction and stating that the lime requirement to neutralize soil acidity induced by ammonium sulfate is three times higher than the lime requirement for ammonium nitrate or urea. This statement has been cited extensively over the years, but until recently was not critically examined and validated in literature.

### Background

Pierre (1928) demonstrated that nitrification of $NH_4^+$-N (ammonium) fertilizers can produce soil acidity due to production of $H^+$ (hydrogen) ions. Adams (1984) later demonstrated that each mole of nitrogen as ammonium sulfate produces four moles of hydrogen, while each mole of nitrogen as urea or ammonium nitrate produces only two moles of hydrogen. This suggests that ammonium sulfate is two times more acidifying than ammonium nitrate or urea – not three times more as predicted by Pierre.

According to Adams (1984), Pierre's prediction invoked the concept of physiological acidity and basicity. This results when plants take up unequal amounts of cations and anions. In the case of ammonium nitrate, which is half ammonium and half nitrate, the uptake of nitrate anions would neutralize some of the acidity produced by the nitrification of ammonium cations.

Ammonium sulfate contains ammonium cations and sulfate anions. Theoretically, uptake of sulfate anions would have the same effect as nitrate anions and would neutralize some of the acidity produced by nitrification of ammonium. But because sulfate is taken up by plants in lower amounts than nitrate, the theoretical buffering effect of sulfate anion uptake would be much lower. Therefore, ammonium sulfate could be expected to express a greater percentage of its full potential acidity.

### New Considerations

Today, changing cultural practices and a better understanding of nitrogen uptake offer new insight into the soil acidification effect of ammonium sulfate.

Until recently, it was widely believed that conversion of ammonium to nitrate must take place before crop roots can take up nitrogen. Today, it is known that crop roots can absorb both nitrate *and* ammonium forms of nitrogen and some crops actually prefer a mix of the two. Research demonstrates that a combination of nitrate and ammonium uptake increases kernel fill in corn (Below, 1995).

The implication for ammonium sulfate is that any nitrogen taken up as ammonium would circumvent the conversion to nitrate.




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If half of the nitrogen applied as ammonium sulfate is taken up before nitrate conversion, then only the remaining half would convert to nitrate, release hydrogen and lower soil pH.

In the years following Pierre's tenure, we have also seen a shift from single-source fertilizer applications to multi-source blends. Today, ammonium sulfate is typically used in conjunction with other nitrogen sources, such as urea, UAN solution and ammonium nitrate. When this is the case, ammonium sulfate is supplied at much lower rates, minimizing the potential for additional acidity that would result from an over-abundance of this product. (An exception would be the case of alkaline soils, where the additional acidity is welcomed, so ammonium sulfate is often recommended to cover 100 percent of the nitrogen needs in these soils.)

Finally, it should be mentioned that fertilizer industry and farming reports have often incorrectly noted that acidification from ammonium sulfate is caused by its sulfur content. While it is true that the conversion of elemental to sulfate sulfur is a process that releases hydrogen and lowers pH, this reaction does not occur when applying ammonium sulfate because its sulfur is already oxidized (converted to sulfate). The acidification induced by ammonium sulfate is strictly due to the conversion of ammonium to nitrate.

## Pierre Values Re-Examined

In November 1998, the International Fertilizer Development Center (IFDC) in Muscle Shoals, Alabama, initiated a three-year laboratory and greenhouse study to examine and test the AOAC value of soil acidification for ammonium sulfate, ammonium nitrate and urea (Chien et al. 2008). Consecutive greenhouse cropping of wheat-maize-wheat-maize-wheat was grown to maturity in three soil types: Sharkey (64 percent clay), Decatur (33 percent clay) and Greenville (17 percent clay). Soil organic matter content varied from 1.40 percent in the Decatur soil to 1.83 percent in the Greenville soil to 2.60 percent in the Sharkey soil. Each soil type was incorporated with 100 kg N/ha for the first two wheat crops, 200 kg N/ha for the maize crops and 200 kg N/ha for the last wheat crop. Nitrogen was applied as ammonium sulfate, urea and ammonium nitrate. Soil pH was measured after each crop. Soil samples after the fourth and last crops were analyzed in the laboratory to determine relative lime requirement (RLR).

All three nitrogen sources decreased soil pH after each cropping as compared with the check. Ammonium sulfate was 1.5 times more acidifying in the clay soil (Sharkey) and two times more acidifying in the sandy (Greenville) and clay-loam (Decatur) soils. The corresponding lime requirement for ammonium sulfate ranged from 1.4 to 2.3 times more than for ammonium nitrate and urea. These results do not support the official AOAC statement that ammonium sulfate requires 3.0 times more lime than ammonium nitrate or urea in order to neutralize soil acidity induced by application of nitrogen fertilizers.

The findings of Chien et al. suggest that the liming cost associated with using ammonium sulfate as a nitrogen source is lower than previously reported. This is significant given growing interest in the use of ammonium sulfate to supply crops with more efficient nitrogen and readily available sulfur.

## Ammonium Advantages

Ammonium sulfate resists nitrogen loss from ammonia volatilization on non-calcareous soils, and therefore does not require incorporation in those soils, whereas ammonia volatilization can be a significant problem for urea regardless of soil type. In studies using $^{15}N$ tracer material, Norman (2004) measured five times less volatile nitrogen loss from ammonium sulfate (<5 percent) versus urea (nearly 25 percent) over a two-week period.

Ammonium nitrate also improves uptake of residual phosphorus and micronutrients. Averaged across 19 sites high in phosphorus, ammonium sulfate performed as well or better than starter applications of 10-30-10 (Roth, 2001) in corn. Another benefit is that root absorption of ammonium-nitrogen acidifies the rhizosphere and suppresses soil-borne diseases such as stalk-rot (Diplodia) and root-rot (Pythium) in corn, root rot (Phymatotrichum) in cotton and take-all (Ophiobolus) in wheat (Huber, 1974).

Use of ammoniacal N sources may help minimize the abundance of nitrate in the soil at a given point in time. As a consequence, the risk of nitrous oxide ($N_20$) emission through denitrification may be reduced (Snyder, 2008). Nitrous oxide is a potent greenhouse gas with a global warming potential that is almost 300 times greater than carbon dioxide. Ammonium may also contribute to increased carbon sequestration by enhancing plant growth through improved nitrogen efficiency, phosphorus uptake and root health.




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## Supplemental Sulfur

Beyond the ammonium benefits, the sulfur content in ammonium sulfate is gaining in importance as more soils fall short of sulfur due to clean air initiatives that have reduced the amount of sulfur fallout from coal-fired power plants (Kelling, 2000). In early planted and/or reduced tillage soils, the need for sulfur is also increasing because cooler soils inhibit sulfur release from organic matter (Lamond, 2001; Randall, 2007). Sawyer et al. (2007) measured corn yield increases in several studies of 15 to 38 bushels per acre in northeast Iowa on fine and coarse-textured soils. Largest yield increases occurred on coarse-textured soils and where corn was showing early-season visual sulfur deficiency symptoms.

## Conclusion

Fertilizer programs intended to maximize nitrogen efficiency and minimize environmental impact often call for ammonium-based fertilizers. The ammonium form of nitrogen is less susceptible to leaching in sandy soils, denitrification under anaerobic conditions in upland and lowland soils, and no volatilization in neutral and acid soils. However, all ammonium-based fertilizers are acidifying to the soil and, depending on soil buffer capacity, original soil pH, and crops grown, may require periodic liming.

Previously, it has been widely accepted that ammonium sulfate requires three times more lime compared to ammonium nitrate or urea, but new research demonstrates that the liming requirement is only about 1.5 to 2.3 times higher. This is significant as more growers consider ammonium sulfate to maximize nitrogen efficiency and minimize carbon footprint.

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**1-844-890-8949** (toll free, U.S./Can.)
**+1-973-526-1800** (international)

**AdvanSix**
300 Kimball Drive, Suite 101
Parsippany, NJ 07054




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